The Pathogenesis of Disc Displacements in the Temporomandibular Joint: A Reassessment of the Role of Close-Packed Positions

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INTRODUCTION

The emergence of all-inclusive Temporomandibular Joint (TMJ) syndromes, notably the TMJ Pain-Dysfunction Syndrome,¹ the Myofascial Pain-Dysfunction Syndrome² and Facial Arthromyalgia,³ has been the major obstacle to the advancement of scientific knowledge in the management of TMJ disorders.⁴⁻⁵

Myopic practitioners continue to rely upon unicausal concepts to account for a wide-ranging set of clinical signs and symptoms, including recurrent headache, pain in the TMJ and/or muscles of mastication, limited or deviant mandibular movements, and the presence of abnormal joint noises during function. These concepts, whether psychogenic or occlusogenic in orientation, tend to propagate unsavoury, cookbook-styled therapeutic regimes and practices, some of which have been shown to foster disastrous consequences.

It is becoming increasingly clear that clinicians and researchers in this field are not dealing with one or two distinct disorders but a particularly diverse group of orthopaedic maladies characterized by individual permutations of predisposing, precipitating and perpetuating factors. Of late, serious efforts have been made towards the subclassification of temporomandibular disorders.⁶⁻¹⁰

One important subcategory previously underemphasized is that of the TMJ Internal Derangement (TMJID).

Internal derangement of the TMJ (TMJID) has been defined as an abnormal relationship of the articular disc to the mandibular condyle, fossa and articular eminence.¹⁰ It is a diagnostic term repre-
senting a mechanical disturbance of the joint (e.g., clicking or locking) with or without associated pain and muscular disorders. It is not a specific lesion.\(^\text{11}\)

Since 1887, many clinicians have ascribed the signs and symptoms of jaw clicking and locking to the anterior displacement of the articular disc.\(^\text{12-20}\) Although these clinical observations were initially controversial, convincing evidence that internal derangements are a reality have come from autopsy findings,\(^\text{21-25}\) condylar path tracings,\(^\text{26-28}\) arthrography,\(^\text{29-34}\) computerized tomography,\(^\text{35-38}\) nuclear magnetic resonance imaging\(^\text{39}\) arthroscopy\(^\text{40}\) as well as surgical observations.\(^\text{41,42}\)

It has been estimated that 10–25\%\(^\text{4,22,35,43-45}\) of the entire population have some type or degree of internal derangement of the TMJ. The preponderance of women in these clinical populations continues to be an enigma. A recent report\(^\text{46}\) on 1009 TMJ patients revealed that 241 (23\%) of them were diagnosed as having anteromedial disc displacements. Of these, 87\% were females, between the ages of 15 and 40 years.

Psychological factors alone cannot obviously account for this female predominance especially since the sex discrepancy among non-patient groups has not been nearly as great as that among patients.\(^\text{47,48}\) Women patients also displayed more clinical signs (particularly TMJ clicking and lateral pterygoid muscle tenderness) rather than merely being more aware of their symptoms, as has been previously implied. In addition, when identifying symptom-free individuals, more men were consistently found to be symptom-free than women.\(^\text{44,49}\)

Male and female subjects should thus no longer be treated as a homogenous conglomerate but as distinct sub-populations in future epidemiological studies.\(^\text{47,48}\) Using the Minnesota Multiphasic Profile Inventory (MMPI), researchers have also shown that the subcategorization of TMJ patients into a myogenic pain group and a TMJ internal derangement group is justified on the basis of psychometric differences.\(^\text{50}\) Psychopathologic factors were also found to be more significant among subjects suffering from myogenic pain and atypical facial pain than among TMJID patients.

The challenge before the dental profession is no longer whether or not internal derangements exist but to define specific criteria, determine the etiologic factors and formulate effective treatment methods for the entity.\(^\text{51}\)

There are as yet no proven etiologic factors for internal derangements of the TMJ. The most probable etiologic factor is macro-trauma to the joint by impact or hyperextension injuries.\(^\text{52,53,54}\) These injuries may occur as a result of fractures, whiplash inci-
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Various occlusal factors have also been implicated. Although scientific literature has not shown conclusively that occlusal problems are a direct cause of TMJ disorders, clinical data do confirm that the two conditions frequently coexist; the nature of this association, however, remains unclear. The purpose of this paper is to present a hypothesis as to how occlusal relationships and certain habitual patterns of jaw use might relate or contribute to the pathogenesis of TMJ internal derangements via recurrent micro-trauma.

TMJ BIOMECHANICS

The TMJ is a freely movable articulation between the condyle of the mandible and the squamotemporal bone (Fig. 1a, b). It is a true synovial joint but possesses certain unique developmental, anatomical and functional characteristics which distinguish it from most other diarthroses. As excellent reviews of its functional anatomy have been published by Bell, Dubrul, Hylander, Mahan and Mohl, our present purpose is to highlight only those aspects that deal strictly with biomechanical load transmission.
As with other synovial joints, the health of articular tissues in the TMJ is highly dependent upon unsustained loading, or rather, on the duration and rate at which forces are applied and removed. Perhaps no joint could demonstrate a greater level of morphofunctional adaptation to the curtailment of stress concentration than does the TMJ.

a) Loose-Packed Positions
The long axis between the medial and lateral poles of each condyle are generally perpendicular to the plane of the ramus. Since the rami diverge posteriorly, the axes of both sides are seldom parallel but often form an obtuse angle of about 145–160° when projected medio-posteriorly\(^5\) (Fig. 2a).

Anatomic and histochemical studies suggest that only the anterolateral aspects of the condyle, the central portion of the articular disc and corresponding aspects of the articular eminence are loaded at maximum intercuspation\(^6\)–\(^8\) (Fig. 1b). From the side, the lateral pole can be observed to lie anterior to an imaginary, movable transverse condylar rotational axis while the medial pole lies behind it (Fig. 2b). Slight opening and closing mandibular movements would therefore effectively shift the loaded contacts lateromedially as well as anteroposteriorly between condyle, disc and articular eminence.\(^\text{57}\)

This ill-fitting of synovial articular surfaces is advantageous in a number of ways.\(^6\) Firstly, deleterious frictional and erosive forces are minimized since the contact area between opposing surfaces is greatly reduced and frequently changing. Secondly, during joint movements, small wedge-shaped intervals that develop around the contact area become filled with small volumes of synovial fluid.
Their shape has been considered an important factor in maintaining efficient joint lubrication and avascular articular tissue nutrition. Thirdly, the combination of simultaneous sliding, spinning and rolling facilitated by this incongruency characterize the complex jaw movement often seen and at the same time, significantly increases the effective range of motion that would otherwise be impossible had the joint surfaces been closely matched.

Of crucial importance in this context is some required understanding of the possible functions of the articular disc. It has often been incorrectly referred to as a meniscus despite the fact that it completely separates the synovial fluid-filled joint space into two distinct and quite different units; namely the superior (arthrodial) and inferior (ginglymoid) compartments. The TMJ is transformed from a simple joint to a complex one by its functioning as a "non-ossified bone" whose superior and inferior surfaces are true articular facets. The presence of an interposing articular disc divides the two potentially destructive shear reactions that would otherwise result from the simultaneous rotation and translation.

The disc also limits the depth to which the condyle is compressed into the soft tissue covering the temporal bone thereby allowing the condyle-disc assembly sufficient freedom to spin and slide over the temporal bone without distorting and damaging the surfaces. This is an important consideration especially since the articular surfaces of the TMJ are lined not with hyaline cartilage but dense fibrous connective tissue. The "destabilizing" role of the disc has been discussed at length in a provocative paper by Osborn.

The articular disc is composed of dense fibrous tissue that is non-vascular and non-innervated except in the peripheral areas. It is thin in its central portion, much thicker anteriorly and thickest posteriorly. Osborn argues that the dense central part of the disc is modelled in response to condylar forces which compress it into the articular eminence thereby thinning its centre and squeezing out a thickened anulus around its rim. This contour does not interfere with free rotatory movement between disc and condyle, yet it effectively resists bodily displacement from the condyle during transatory movements. The width of the articular disc space does not remain constant but changes with the alteration in inter-articular pressure (Fig. 3). Although joint stability is primarily dependent on proper co-ordination of muscle activity, it is the contour of the disc that makes possible the maintenance of sharp surface contact of the moving parts by permitting a thicker portion of the disc to be rotated into the space when it widens and by rotation back to its centered position when the space is minimal.

Stability in the resting joint is sustained by the action of muscle tonus as modified by the effect of gravity via the myostatic stretch.
Fig. 3. Jaw movement cycle during mastication.
(a) Maximum intercuspation
(b) Postural (clinical rest) position
(c) Opening rotation phase
(d) Translatory phase
(e) Functional anterior close-packed position (FACP)
(f) Closure phase
(g) Functional posterior close-packed position (FPCP)

reflex. Juniper\textsuperscript{66} had noted that even at postural rest position, there was recordable activity in the superior belly of the lateral pterygoid which was only abolished on opening or protruding movements of the jaw (Fig. 3b). Gentle anterior positioning of the condylar head is apparently important in the normal person at rest.

The relative movement in the disc-condyle complex during the early part of opening cycle is essentially that of posterior rotation of the disc on the condyle (Fig. 3c). Notice that although the inferior belly of the lateral pterygoid muscle is in a state of contraction, the connective tissues in the bilaminar zone gradually assume a functional state of rest as the posterior margin of the condylar articular facet is brought closer towards the posterior band of the disc. Pure rotation, however does not frequently occur (ie. without volition) and a certain degree of translation is inevitable during
any functional jaw separation.

Stability during the translatory cycle is maintained by firm contact between the disc-condyle assembly and the eminence. This is accomplished by muscle action primarily involving the posterior temporalis in combination with the inferior belly of the lateral pterygoid\(^6\) (Fig. 3d).

During power strokes, (e.g., when teeth are brought to bear against a bolus of food) stability against condylar distraction is ensured by action of the superior belly of the lateral pterygoid. Its holding action as applied to the pterygoid depression on the neck of the condyle and its firm anterior rotatory traction as applied to the articular disc permit the return movement of the translatory cycle to be controlled as the thicker posterior band is firmly drawn into the widened disc space created by the torquing of the mandible (Fig. 3f).

During maximum intercuspation stability is provided by the occlusion of the teeth themselves (Fig. 3a). This allows muscle action to fall back to its resting level as the mandible once again assumes its postural position (Fig. 3b).

It is noteworthy that because of unusual masticatory requirements the condyles of the human mandible are not normally braced deeply in the articular fossa during intercuspation but balanced by the muscles of mastication on the slippery slopes of the articular eminentia with the thin intermediate zone of the articular disc properly interposed. As previously mentioned, the condyles not only spin and roll but also slide along their respective articular eminence during grinding movements.

b) Close-packed positions of the TMJ

In any diarthrosis, there is a position usually occurring at one extreme of the most habitual joint movement, in which opposing articular surfaces become maximally congruent.\(^5\)\(^3\) No further movement in that direction is possible since periarticular connective tissues become fully spiralized and tense when these so-called closepacked conditions are assumed. These, therefore, represent border situations seldom utilized except when a special effort is to be undertaken. Interestingly, most fractures and joint derangements tend to occur here because of the comparative rigidity and the likelihood of enormous stresses being generated at this position. Protective reflex contraction of the appropriate musculature is the rule rather than the exception whenever these conditions are approached. The repetitive use of these positions, whether conscious or unconscious, must therefore constitute parafunction.

The TMJ has two such close-packed positions, one posterior and
Fig. 4a. Inferior view of the cranial base. A—A' and B—B' represents frontal sections across the glenoid fossa.

Fig. 4b. Distribution of load to the condyles when clenching at maximum intercuspation. Frontal condylar sections were taken at A—A'.

Fig. 4c. Condylar loading pattern when the left working side (ws) condylar is at the FPCP and the right non-working side (nws) condylar is sliding up the articular eminence. Frontal section of the left condyle was taken at B—B'. Silhouettes of teeth represent a situation where there is an effective anterior guidance.

Chewing is characterized by the working (food)-side condyle (The working-side condyle is the condyle on the side towards which the mandible moves in any lateral movement.) moving to a posterior, lateral position early in the closing stroke. The harder and more resistant the food, the more lateral the closing pattern. The working-side condyle is thus forced to negotiate the lateral border ranges of joint function only in these special instances since maximum masticatory muscle contraction cannot safely occur until after adequate joint bracing has been achieved. The Functional Posterior Close-Packed Position (FPCP) represents the extreme of this working side border pathway. At this position, we would expect the lateral and superior aspects of the working side condyle and the corresponding portions of the temporal fossa to be heavily loaded (Fig. 4c). This is entirely consistent with earlier autopsy findings that there was a predominance of regressive remodelling on the lateral parts of the eminence, that the disc is thinnest the other anterior (Figs. 3e, 3g).
laterally and that any failure of adaptation to loading (i.e., degenerative joint disease) is usually first seen on the lateral aspects of most TMJs.\textsuperscript{21-25,79-73}

We will return to the concept of the development of arthrotic lesions when the question of tissue responses to biomechanical loading is further considered.

The Functional Anterior Close-Packed Position (FACP) is of particular functional importance to carnivorous mammals in the prehension of their prey. It is not unusual to find both condyles braced at their FACPs as the predator prepares to pounce on its prey. From this stabilized joint platform, powerful masticatory muscles can develop their maximum contraction force.

In the everyday context, the FACPs are most often assumed when an individual takes an unusually large bite from an apple or whenever he fails to restrain a yawn. The FACP is also involuntarily assumed during whiplash incidents. With the rapid extension of the head in a whiplash incidents, the supra-and infrahyoid muscles cannot lengthen rapidly enough so they hold back on the mandibular symphysis whipping the condyles excessively forward towards the FACP. At FACP, the condyle is precariously perched at its ligamentous limits, in its most anterior relation to the apex of the articular eminence, or frequently, even on the anterior-inferior incline of the latter, where it is particularly prone to traumatic injury, both extrinsic and intrinsic.

As there is no capsule at the medial half of the anterior aspect of the TMJ, the synovial membrane lining the superior cavity anterior wall is supported only by loose alveolar connective tissue. The capsule-like structure at the lateral half of the anterior aspect of the joint is also made up of a similar tissue. This anatomical "Achilles heel" of the TMJ is probably responsible for the high incidence of TMJ pain and dysfunction following chronic hypertranslation of the condyle and whiplash injuries.\textsuperscript{59} Because hypertranslation cannot be prevented by a sturdy anterior capsule, there is a potential for trauma to the synovial tissues and the foot attachment to the superior belly of the lateral pterygoid each time we use this extreme joint position. The collateral disc ligaments can also become overstretched as the disc is forced to rotate backwards over the condyle (Fig. 3e). The situation is made worse if the subject happens also to have a very steep eminence.\textsuperscript{6}

The TMJ is perhaps the only joint of the human body that can be dislocated without the action of an external force.\textsuperscript{74} Similar dislocations, for instance in the shoulder, occur only after a first injury has traumatized the capsule and its ligaments. Usually after wide mouth opening, the closing movement begins with a retraction of the mandible which brings the condyles into a safe position.
Fig. 5. Submental vertex views of condylar inclinations, shapes and widths in (A) Normal subjects, and (B) Chronic unilateral chewers. THA, CS, OS represent the terminal hinge axis, chewing side, the orbiting (translating) side respectively.

Fig. 6a. Armamentarium for Doppler Auscultation (doppler unit, detachable transducer, stethoscope, ultrasound transmission gel).

Fig. 6b. Medial pole sounds indicative of medial pole changes can be auscultated using a 4MHz transducer while hinging the patient’s mandible.

behind the height of the articular eminences before the elevators act with full force. If this accurate timing of muscle action is disturbed (e.g., in yawning) and the inferior belly of the lateral pterygoid remains in a state of almost spastic contraction at the beginning of closing movement instead of relaxing, the elevators will exert their force while the condyle is still held in its FACP. A dislocation will often result.

As discussed previously, the shift of condylar contact occurs from lateral to its medial aspect during opening. Discs with loose col-
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lateral ligaments would tend, therefore, to be squeezed like a melon-seed, postero-laterally behind the condyle. The wide-open (eminence) click may in fact be caused by the condyle overriding the anterior band of the disc. Medial pole changes, although rare in comparison to its lateral counterpart, can be non-invasively confirmed by Doppler Auscultation using this shifting condylar load principle.\(^{75,76}\)

Anyone who has ever taken a hinge axis recording\(^{77}\) knows that it is possible to manipulate the mandible in such a manner that the locating pin will rotate around itself without movement once the true so-called Terminal Hinge Axis (THA) is located. Since the capitulum is at right angles to the ramus, as already discussed, the only place the condyle could rotate on a true and reproducible axis and still be at the “apex of force” position would be at its medial pole\(^78\) (Fig. 5A). Thus, by auscultating over the pretragal region, increases in frictional contact in areas devoid of the articular disc’s protective coverage can be picked up during hinge axis opening and closing as moderate to coarse crepitations depending on the (degenerative) state of the medial pole (Fig. 6a, b).

Although some authorities\(^{79,80}\) have provided evidence to suggest that a greater condylar reaction force is present on the balancing side (where most of the load will be concentrated on the medial condylar aspects), it deserves to be mentioned that such a load is a moving one unlike the lateral portion of the working side where the point of load on the condyle does not move very far.\(^6\)

c) Role of teeth in joint bracing

When teeth are out of contact, non-dental (muscle, joint and oral mucosa) sensory and proprioceptive signals dominate guidance of chewing movements. Sensory input from periodontal receptors come into play as the teeth are stimulated by contact of food and/or each other, further modifying guidance. However, at maximum intercuspation, the passive, mechanical fit between opposing posterior teeth overrides all other influences.\(^6\) In other words, the neuromuscular system moves the working side condyle posteriorly and laterally in early closure further than required for intercuspation, and the teeth glide it forward and medially during final closure.\(^{68,69}\) The TMJ is the only joint system with a rigid end point of closure\(^5\) and the occurrence of forceful occlusal guiding contacts in most patients\(^{68,69}\) is convincing evidence that tooth positioning of the jaw is a common and a normal part of the chewing process.

It is an important physiological requirement for any joint to be braced during peak function before muscles can safely exert their maximum contraction force. The interdigitation of thirty-two teeth compressed into their individual gomphoses during a heavy clench aptly substitutes for the stability usually provided by the
"close-packing" of joint surfaces. In other words, although the TMJ's have the capacity to articulate and be "weight-bearing" at border positions, they are required to do so only occasionally. In healthy masticatory systems, the dento-alveolar complex is the component that normally bears most of the biomechanical forces generated while functioning at or near maximum intercuspidation. As in other joints, the final stages just short of the close-packed position tend to be of greater physiological importance. The occlusal relationship of the opposing cusped posterior teeth thus preserves this functional intraborder condylar position by three-dimensionally suspending the condyle-disc assemblies in their respective glenoid fossae (Fig. 4b).

d) Tissue responses to biomechanical loading and its role in the development of disc displacements

Although TMJ growth ceases at about twenty years of age, the hard and soft tissue layers of the articulating components continue to undergo structural changes throughout life. This remodelling response to biomechanical loading is normally so slight that joint form appropriate to smooth function is maintained. Remodelling, on the other hand, may be so advanced that it causes Deviation-in-Form (DIF) of the articulating components. These departures from the normal rounded articular surface contours may act as mechanical impediments to diarthrodial movements, further intensifying the loads transmitted to the TMJ joint.

DIFs are not only due to the remodelling of hard tissue but also, to a large extent, to variation of subarticular soft tissue thickness. Thickening of the subarticular soft tissue layers was apparently related to the cartilage formation from a load stimulating a proliferative response in the undifferentiated mesenchymal layer.
Predegenerative changes begin to occur when this layer is used to such an extent in cartilage formation during remodelling that it subsequently disappears. Fig. 7 summarizes the continuum of changes occurring in the TMJ throughout life. Thus, it is the residual amount of undifferentiated mesenchymal cells that finally determines whether a particular tissue site can continue to respond to biomechanical stress via a physiologic remodelling process or must gradually succumb to arthrotic change.

DIF were predominantly localized to the lateral parts of the joints as these aspects were exposed to the greatest functional and parafunctional loads. Because there is more of this "protective factor" (i.e., undifferentiated mesenchyme) in the condyle than the temporal component, the frequency of DIF was likewise higher in the condyle than the temporal component. Since there is no such tissue layer in the disc, it can only passively adapt to the changes occurring in the other articulating components by becoming increasingly thin.

Arthrotic lesions, for similar reasons, were usually seen in the disc, temporal and condylar components, in descending order of frequency. Disc perforations were mostly confined to the lateral aspects of the central portion of the disc where it has been overly thinned. In the temporal component, arthrotic lesions were commonly found on the lateral wall of the fossa, laterally on the posterior slope of the eminence, and on the crest of the eminence. Arthrotic lesions in the condyle were rare in comparison and usually occurred in association with disc displacements.

Solberg et al. reported the frequency of disc displacements to be 12% among 95 young TMJs at autopsy. It is therefore appropriate that we address some of the theories concerning the pathogenesis of the disc displacement.

Firstly, the articular disc is rigidly attached to the medial and lateral poles of the mandibular condyle via strong collateral ligaments. These limit gross movement between the disc and the condyle to rotation although slight lateral shifting movements of the disc may be present.

Secondly, the superior belly of the lateral pterygoid muscle or rather the superior pterygoid muscle not only inserts into the disc but also into the pterygoid fovea of the mandible. Isometric contraction of the superior pterygoid e.g., during jaw closure would pull the disc forward independently of the condyle only if the muscle's insertion into the pterygoid fovea was ruptured. Thus, earlier theories that disc displacements are initiated by a hyperactive superior lateral pterygoid must be re-examined as the bodily displacement of the disc from the condyle cannot normally occur as long as the discal ligaments remain functionally.
intact. On the contrary, there is evidence\textsuperscript{85,88} to suggest that dysfunction of the superior belly of the lateral pterygoid is more likely the result of TMJID, rather than its cause.

In other words, in order for a disc to be bodily displaced from the condyle there must already have been an appreciable degree of looseness in the periarticular connective tissues. This can be the result of two distinct processes, namely, a) actual elongation and/or tearing of the collateral disc ligaments themselves, secondary to either extrinsic trauma and/or recurrent strain of an intrinsic nature, and b) relative or apparent "laxity" of the collateral disc ligaments, secondary to regressive remodelling of the condylar bone underneath the disc.

Perhaps a combination of the above occurs in reality. Indirect support for the above hypothesis have come from careful examination of a group of dysfunctional chronic unilateral chewers with disc displacements.\textsuperscript{89} The non-chewing side usually exhibits a greater range of condylar trajectory. The non-chewing condyle is usually seen "subluxating" over the eminence although radiographic changes in condylar form are rare. Eminence changes, however, can be observed in those advanced cases where disc displacements have already occurred for some years. Disc displacements occurring on the habitual chewing side, on the other hand, is more often characterised by radiographic changes on the lateral aspects of the chewing side condyle. In contrast, the range of condylar translation on the habitual chewing side was usually found to be within normal limits. These preliminary findings suggest that disc displacements occurring on the non-chewing side are more likely due to elongated ligaments whereas those occurring on the habitual chewing side are probably secondary to excessive remodelling on the lateral aspects of the working-side condyle. A recent cross-sectional survey found no statistical correlation between chewing side preference and mandibular dysfunction symptoms.\textsuperscript{90} The investigators, however, made no attempt, whatsoever, to document TMJ changes secondary to the unilateral function.

Some authorities, nevertheless, maintain that disc displacements are the consequences rather than the cause of previous histologic changes.\textsuperscript{91} Disc deformation was commonly associated with disc displacement\textsuperscript{24,25,92} while changes of soft tissue character in the other joint components were also evident. Although the final verdict is not yet available, all workers agree that without the protection of the interposing disc, "exposed" portions of the condylar and temporal articulating components will become increasingly subjected to the destructive forces described by Hjortsjo.\textsuperscript{64}

Others\textsuperscript{84,93} have attributed the anteromedial displacement of the disc to the thinning of the posterior band of the disc secondary to
a host of factors including iatrogenic jaw retrusion, bruxism, lack of posterior support and the passive adaptation of the disc to the changes occurring in the opposing components of the TMJ. Since the biconcavity may contribute to keeping the disc in a normal position over the condyle during jaw movements, it is conceivable that a flattening of the posterior band might allow the disc to slide over the superior crest of the condyle especially during the chewing of a resistant bolus when the superior belly of the lateral pterygoid muscle is actively contracting. Incompetence of the posterior disc attachments has also been implicated as a contributing factor in the development of anterior disc displacements.

Componential form, perhaps selected by functional demands during growth, seems to be yet another influential factor. Joints with frontally flat, gabled-shaped or totally irregular condylar forms generally show more changes. Each TMJ component seems to have its own individual capacity for maturity, adaptation and degeneration. Early maturity of the TMJ combined with greater tendency for ligament laxity, condylar retropositioning and a larger mesio-distal size discrepancy between the condyles and the temporal fossae in asymptomatic women when compared to asymptomatic men, may account for the skewed sex distribution among patients with craniomandibular disorders in general and TMJID in particular. Autopsy findings also indicate that adaptive joint changes followed by local degenerative changes are quite common and can be expected by the third decade of life.

The important question is no longer whether the TMJ is loaded but on the degree of such loading i.e., on the frequency, duration, magnitude, direction and location of the biomechanical loading within the joint. The amplitude and angulation of the force transmitted to the joints are greatly dependent upon the angle of the tooth resistance, the size, type and site of tooth contact within the arch, the craniofacial morphology of the individual as well as the cross-sectional area, direction and relative contribution of muscles on the right and left sides, particularly those of the masseter, medial and lateral pterygoid groups.

Thus, regardless of one’s conceptual orientation to the aetiology of TMJ disorders, it appears that biomechanical factors are significant in the causation and localization of these tissue changes.

e) Factors causing an alteration in TMJ loading

Forces transmitted to the TMJs will be discussed under the following headings:

i) Forces generated during the tooth contact phase.

ii) Forces generated during the translatory cycle.

iii) Forces related to the loss of the functional intraborder (loose-packed) condylar position at maximum intercuspation.

iv) Forces specifically related to the utilization of iatrogenic close-
packed positions in full-mouth rehabilitation.

i) **Forces generated during the tooth contact phase—Functional considerations**

As previously mentioned, the working side condyle typically goes to its posterior close-packed position whenever a tough or resistant bolus is chewed. If the anterior guidance is effective, the canines are usually the first teeth to come into contact as the teeth approach maximum intercuspation.\(^{99}\) If, however, the individual exhibits a type-C eccentric canine relationship\(^{100}\) (i.e., mandibular canine discluding off the distal aspects of the maxillary canine), the guiding incline provided by the upper canine would tend to dislocate the working side condyle, already at its ligamentous limits, still further perhaps even to its plastic failure zone (Fig. 8a, b). The tooth resistance angle has been shown to be an important consideration in the estimation of condylar reaction forces during isometric tooth clenching.\(^ {80,98}\)

Steep anterior guidance does not appear to expose the teeth to extreme lateral forces.\(^ {69}\) The tooth gliding contacts while entering and leaving the intercuspal position have been shown to be of short duration and low magnitude when compared to forces generated in intercuspal position.

By virtue of their shape and position in the arch and their acute sensitivity to pressure changes,\(^ {101}\) anterior teeth are especially suited to provide both mechanical and neurophysiological guidance of the mandible into intercuspal position during mastication. Proper anterior tooth relationships will even encourage the adoption of a more verticalized chewing pattern.\(^ {102}\) Horizontal chewing patterns, in contrast, will expose posterior teeth to more
wear, the periodontium to more occlusal trauma and the joints to more damage secondary to the greater use of the FPCPs.

Larger overjet was found to be highly associated with degenerative joint disease and disc displacements in a recent autopsy study attempting to correlate occlusal factors with morphologic changes in the TMJ. Retroclined upper incisors and artificial maxillary incisor crowns with overcontoured lingual surfaces can also trigger avoidance engrams thereby programming the jaw into a more distal arc of closure.

In addition, if the anterior guidance were less steep than the condylar guidance (e.g., in severe class III malocclusions), the direction of condylar rotation would be antagonistic to the closing rotation of the mandible whenever the mandible moved from an eccentric position toward centric occlusion. This would interfere with normal elevator muscle activity besides subjecting the disc-condyle assembly to destructive shear couples.

There is also a greater likelihood of encountering non-working side tooth contacts during mastication when the anterior guidance is ineffective. These contacts can evoke involuntary contraction of the contra-lateral pterygo-masseteric musculature.

Non-working side contacts have also been shown to dramatically alter the distribution of muscle activity during isometric jaw clenching, and are likely to affect the nature of the reactions at the TMJs. It may be conjectured that gnathologic canine-disclusion schemes, by mechanically denying the individual the capability to make stable eccentric cross-arch dental contacts, could be beneficial since the jaw elevators require the mandible to be effectively braced against the cranium before they can achieve their maximum contraction. Patients occlusally rehabilitated in this manner should thus not be able to exert their heaviest clenching force, either functionally or parafunctionally, in any tooth-contact jaw relationship except in the meticulously co-ordinated centric occlusion prescribed by the dentist.

Evidence that anterior tooth contacts are as important as posterior molar contacts has come from a recent study comparing clinical occlusal stability in 128 TMJ patients to 71 age-matched young adults without masticatory disorders. Occlusal stability was defined by the distribution of molar, premolar, canine and incisor zones of contact holding a mylar strip at firm intercuspal closure. Bilateral, canine contacts and heavy as well as light incisal contacts were found to be associated with the control group while their absence was associated with TMJ group. Although a lack of molar contact at intercuspal position was also significantly associated with TMJ disorders, bilateral molar support per se was not found to be as good a predictor of normal function as bilateral canine contacts.
The investigators speculated that occlusal instability might have been a preceding and temporary phase as the system sought to re-establish symmetry and stability at the expense of dento-alveolar, articular and jaw posture (neuromuscular) adaptation. They went on to suggest that deficient molar support should be corrected and stabilized through canine contacts. Bilateral canine contacts during an intercuspal position clench might very well be as important a factor in stabilizing the mandible transversely as the molars are vertically.

Electromyography and kinesiographic studies also indicate that improved occlusal stabilization produced shorter relative contraction times in jaw elevator muscles and consequently, less load on the muscle as well as the dento-periodontal complex. Reduced intercuspal pauses due to occlusal instability are thought to play a role in a circulatory aspect of myogenic pain and some investigators believe that stabilizing the occlusion by occlusal adjustment increases these intercuspal pauses and facilitates blood flow in the myofascial tissues.

Incisor point tracings of subjects with severely worn teeth have flattened tops, indicating the lack of any anterior tooth guidance. Condylar tracings of these individuals also exhibit extreme lateral movements and opening movements directed towards the non-working side. Further, because of the lack of precision in the occlusal interface, no characteristic pause at intercuspal position can be observed. It is evident that the attrited dentition cannot as effectively protect or stress-break the system and thus much of the joint bracing has to be undertaken by the bony and ligamentous components i.e., there is a greater utilization of joint border positions.

Studies show that bruxers and denture wearers usually exhibit as much as five and four times the normal amount of mandibular side shift respectively. Mandibular side shift or Bennett movement is the bodily lateral shift of the mandible that occurs during lateral jaw movement. It is a measure of the looseness of fit or slackness of the condyles in their fossae. Excessive tooth wear and primitive diet considerations make aboriginal groups likely candidates to develop degenerative TMJ changes. The correlation between degenerative joint disease and dental attrition has been noted by several authors.

Although asymmetry in slides from CR to CO have been associated with dysfunctional signs, most conventional occlusal analyses based on classic gnathological principles do not address the importance of those morphologic occlusal features that encourage the use of posterior close-packed positions. On the contrary, gnathologists have for years strived religiously to remove natural protective inclines in a mistaken attempt to force the jaw to function.
at its border limits.

**Parafunctional considerations**

Nocturnal bruxism is probably one of the major causes of degenerative joint disease.\(^1\)\(^1\)\(^2\)\(^3\) Firstly, the protective neuromuscular reflexes that are normally activated whenever close-packed joint conditions are approached in a conscious individual are conspicuously inoperative when we sleep. Secondly, the shear, compressive and torsional forces that are generated during nocturnal bruxing episodes are usually of a more persistent character and thus have a greater tendency to compromise local fluid retention and articular tissue nutrition.

Sleep laboratory researchers have observed that individuals with similar levels of nocturnal electromyographic hyperactivity do not necessarily share common morning symptomatology.\(^3\) While some might complain of pain in the joints and the masticatory muscles, others may be completely symptom free.

During these paroxysmal attacks of nocturnal bruxism, the resting mandible is suddenly wrenched towards the opposing jaw by the indiscriminate contraction of the jaw elevator muscles.\(^4\) Microtrauma sustained from the chronic unconscious use of the FPCP contribute towards ligament laxity and degenerative joint disease.

Differences in the sleep posture and the occlusal schemes of these bruxers seem to influence their ability to tolerate such parafunctional loads. Rugh\(^5\) has speculated that individuals with large canines are less prone to develop joint microtrauma because their lower jaws are very quickly guided by these anterior teeth into intercuspal position where it is securely braced from further harmful torquing. Torquing of the mandible is also less likely to occur when there are bilateral “balancing” tooth contacts. Dentitions of “symptomless” bruxers usually tend to exhibit such features.

**ii) Forces generated during the translatory cycle**

In all synovial joints, normal function demands that sharp surface contact of the moving parts be maintained at all times. Although ligaments offer support to the joint and restrain movements that tend to dislocate the articular surfaces, joint stability is primarily furnished by co-ordinated muscle activity. Because of the convex-concave relationship between the condyle and the inferior surface of the disc, when the condyle glides anteriorly, the disc will have a relative posterior glide on the condyle until the collateral ligaments tighten. At this point, rotation ceases and to complete the functional opening range of jaw movement, the disc-condyle complex has now to translate down the articular eminence.

During rotation, the retro-discal tissues are in a state of rest whereas during translation they become increasingly tightened.
(Fig. 3d). Since we know that in order to maintain a state of orthofunction the periarticular connective tissue should rarely exceed 70 to 80% of its total length in function, we must emphasize to our patients the need to adopt a large amount of rotation at the beginning of the jaw opening cycle such that only a short anterior transulatory glide is required to complete the functional range of motion. As a preventive measure we must also totally discourage our patients, especially those who have a history of ligament laxity, from using their FACPs.

A significant relationship has been demonstrated to exist between systemic joint laxity and TMJ ID in the female patient population. Even though the absolute jaw opening in women is known to be less than that in men, the angle of maximal passive opening of the TMJ in women was significantly larger, indicating that women may in fact exhibit wider relative jaw opening.

These findings suggest a possible physiologic explanation for the extremely high female-to-male ratios reported in TMJ populations. Women in their third trimester, individuals with connective tissue disorders and young adults who may be suffering from hormone-induced increased collagen metabolism have found autorotative jaw exercises and isometric techniques based on Proprioceptive Neuromuscular Facilitation concepts to be beneficial in alleviating those TMJ symptoms caused by this form of incorrect jaw use. Cheerleaders, opera-singers, oral sex advocates and others who habitually hypertranslate or overutilize their FACPs are more likely develop adaptive changes on the crest of the articular eminence and on the superior and medial aspects of the condyle than elsewhere.

They are also particularly prone to develop postero-lateral disc displacements and a condition for which Rocabado has coined the “bulging disc” syndrome (Fig. 9). Because of the lack of viscoelasticity in the periarticular connective tissue due to over-stretching, sufferers of this syndrome characteristically adopt a large anterior transulatory glide at the beginning of the opening cycle where rotation should be taking place. These patients constantly talk in a protruded fashion and often exhibit unilateral or bilateral deviations of the mandible during the opening and closing phases when the condyle “subluxates” over the articular eminiae.

Wide open (eminence) clicks are common in this category of patients and these should not be confused with the reciprocal clicking associated with the more classical anterior-medial disc displacement. These patients, usually female, will also complain of having difficulties in finding a comfortable mandibular position and in order to accommodate, they tend to adopt abnormal jaw movements, further aggravating the ligament situation.
Subjects with severe Angle's Class II malocclusion also tend to develop similar patterns of TMJ remodelling. These changes might perhaps be, in part, due to speech demands or other functional jaw activity requiring excessive translatory excursions. Arthrographic studies have also shown a significant correlation between condylar hypermobility and disc displacements with reduction. Patients with hypermobility also tend to have a 60% increase in the superior cavity passive fill volume and a 20% increase in the inferior cavity.

Prominence of the articular eminence has also been associated with disc displacements. In order to maintain surface contact of the articulating parts during the translatory cycle, the disc has to rotate posteriorly on the condyle each time the disc-condyle complex moves forward in relationship to the condyle. Steeper articular eminences therefore demand greater amounts of posterior rotation of the articular disc on the condyle thereby injuring the collateral disc ligaments. Other categories predisposed to this form of disc displacements must include individuals who recurrently subluxate, chronic unilateral chewers and those with grossly asymmetric jaws especially if they also happen to have steep eminences. The non-chewing or orbiting condyle in the unilateral chewer and the condyle on the shorter side of an asymmetric mandible have generally to translate a great deal more than its counterpart during normal function.

It should be noted that although these hypertranslation-related postero-lateral disc displacements occur, with time they become indistinguishable from the anteromedial variety associated with the use of the FPCP. This is due to the fact that at maximum intercuspation, any loosely held disc would tend to be displaced antero-medially in relation to the condyle because of the pull of the superior belly of the lateral pterygoid and the narrower lateral interarticular space between the condyle and the temporal bone at maximum intercuspation.
iii) Forces related to the loss of the functional intraborder (loose-packed) condylar position at maximum intercuspation

The benefits of maintaining a tooth-protected loose-packed condylar position is evidenced by the fact that over 90% of population do not have their condyles braced in a border position when their teeth are fully intercuspated.\textsuperscript{127,128} In fact, some authorities feel that a short anterior and vertical occlusal slide from the retruded contact to intercuspal position without lateral deviation may serve a protective function for the TMJ.

Based on their finding that the activity of the superficial fibres of the masseter, medial pterygoid as well as the anterior temporalis is significantly reduced when subjects clenched on their natural retruded contact inclines, Gibbs et al.,\textsuperscript{84} speculated that perhaps this is the mechanism that protects the posterior band of the disc from injury by the condyle during bruxing and chewing. When posterior teeth can no longer stress-break the joints both mechanically and in the neurophysiologic sense previously described, the latter must bear more of the functional masticatory load. Extensive loss of teeth, especially molars and premolars, and dental attrition have also been found to significantly influence bone remodelling in both condylar and temporal components.\textsuperscript{109-111,129}

Perhaps one of the most overlooked causes of abnormal joint loading is iatrogenicity.\textsuperscript{4,54,55,81,129-131} We, as dentists constantly place demands on the adaptive capacity of the patients by our simplest restorative procedures. Most occlusal restorations, especially amalgams, are shy of contact. When an entire quadrant is completed in this fashion, a reposturing of the joint must occur in order to regain maximum occlusal contact. This adjustment, although initially involving only the neuromuscular system, can also cause tooth migration and/or eventual joint remodelling.

Because the adaptive capacity of the patient can be over-exceeded we should strive to support and reinforce Centric Occlusion (CO) [i.e., the relationship of the mandibular to the maxillary teeth when the patient closes to the position of maximum intercuspatation] rather than contribute to its destruction.\textsuperscript{131} The casual use of border techniques in oral rehabilitation whether it be in the form of full-mouth occlusal equilibration, extensive prosthodontic reconstruction, orthodontics or orthognathic surgery should thus be re-examined.

iv) Forces specifically related to the utilization of iatrogenic Close-Packed Positions in full-mouth rehabilitation

Centric Relation (CR) has evolved more as a clinical concept rather than a biologic entity. Prosthodontists needed to record a transferable horizontal axis of mandibular rotation in order to logically make use of interocclusal records at open vertical dimensions, mount casts on articulators and analyze occlusal relation-
ships in the absence of the patient. CR was, in fact, defined as the relationship of the mandible to the maxilla when the condyles are in their terminal hinge axis, irrespective of tooth contacts. Perhaps the most significant development in recent years has been the universal recognition of the contribution of the soft tissue components to the health and biomechanics of the TMJ.

Although earlier definitions of CR merely considered the position of the condyle in the glenoid fossa without regard to the proper alignment of the disc, current definitions of CR pay close attention to it. CR has been recently defined as a bilateral orthopaedic position and the most superior position of the condyles at which a hinge axis movement can be recorded provided the discs are not displaced. Dawson now defines CR as "the relationship of the mandible to the maxilla when properly aligned condyle-disc assemblies are in their most superior position against the eminentia, irrespective of tooth position or vertical dimension."

Since at CR the medial poles of the condyles are bilaterally braced against the superior-most portion of their reciprocal fossa contour, it is not possible to move forwards or backwards without moving downwards. This "apex of force" position can be either attained passively by the Bimanual Jaw Manipulation technique or actively using a modified anterior biting jig or a leaf gauge. This term therefore represents a rigidly specified cranio-mandibular relationship whereby both TMJs are simultaneously made to assume their respective iatrogenic posterior close packed positions (IPCP). Some "authorities" have implied that CR is a naturally occurring functional jaw relationship frequently used by the normal dentate population during functional jaw activities like chewing and deglutition. These clinicians have misinterpreted Gibbs’ Replicator research findings and have obviously confused the border position used by the working-side condyle when chewing a resistant bolus (i.e., FPCP) with CR.

It must be re-emphasized that the FPCP is attained by one condyle at a time (i.e., the working-side condyle) whereas the IPCP is attained by both condyles simultaneously. Normally, as in the former case, the lateral superior aspects of the working-side condyle are loaded in contrast to the latter situation (i.e., CR) when the medial superior or the medial anterosuperior aspects of both condyles are loaded depending to a certain extent on the exact CR recording technique advocated. Furthermore, functional jaw movement studies conducted in normal dentate subjects have shown, both consistently and conclusively, that gnathologic hinge-axis type movements were never observed during mastication or other functional jaw activity.
This is not to imply that patients cannot be made to function at CR since this can be done by simply re-establishing Centric Occlusion (CO) at this iatrogenic craniomandibular relationship. Nevertheless, it must be realized that Centric Relation Occlusion (CRO) [i.e., a tooth to tooth position in which there is maximum occlusal contact and the disc/condyle/fossa relationship is in the centric relation position bilaterally] is often an artificial situation created by the dentist at the inevitable expense of bone remodelling and ligament health.

Recently, tissue reactions in monkey TMJs were studied following retrusive guidance of the mandible. The natural protective tooth “interferences” between CR and CO were removed and bilateral distalizing inclines introduced to guide the mandible into a retruded position during mouth closure. After five weeks, the joints were radiographically examined, histotechnically processed and sectioned for light microscopy. In contrast to the untreated animals, the experimental monkeys demonstrated pathological changes in the posterior band of the disc and posterior disc attachment. Similar lesions have been described in human TMJs with internal derangement. Flattening of the posterior band and the associated tissue changes in the posterior disc attachment caused by retrusive guidance during the five week period might well have contributed to the development of disc displacements in the long term.

Most authorities, however, accept that a stable and precise therapeutic CO is neurophysiologically important in the reprogramming of muscle engrams via a positive periodontal feedback mechanism. CR remains a prosthetically convenient reference for extensive oral reconstructions mainly because of its relative reproducibility. The temporary stability obtained when the condyles are simultaneously made to assume their iatrogenic close-packed positions greatly facilitates the co-ordination of the occlusal interface.

The biomechanical benefits of a loose-packed condylar position at maximum intercuspation, nevertheless, is lost whenever CRO conditions are imposed. Celenza has reported that within a year, articular (bone and ligamentous) remodelling appears to take place relieving the joint of constant border apposition. Thus, the re-establishment of the important intra-border space is a testimony that extreme or border path relationships are not physiologically optimum or tolerable. Clinically, a still more retruded CR recording is demonstrable despite the lack of evidence of occlusal wear.

Recent work by Hobo on iatrogenic mandibular movements have provided us with a mathematical insight into the post-treatment articular remodelling phenomenon in patients rehabilitated at CRO. Working from within the limits of the available
condylar "buffer space" at CR, Hobo found that a relatively steep sagittal incisal (anterior) angle setting was necessary in order to ensure an even disclusion of posterior teeth. From his calculations, the anterior disclusive angle i.e., the sagittal incisal inclination [N.B. anterior teeth disclusion is occasioned by the descent of the mandibular anteior teeth against any available maxillary tooth surface, resulting in disclusion of the posterior teeth] should be on an average 12—25° (minimum 11°) greater than the condylar disclusive angle [N.B. condylar disclusion is occasioned by the descent of the condyles against the articular eminence, resulting in disclusion of posterior teeth]. Because patients usually feel uncomfortable or restricted whenever the anterior disclusive angle exceeds the condylar disclusive angle by more than 10°, it is safe to presume that the higher angles stipulated by Hobo are seldom realized in the clinical situation.

Other authorities believe that no correlation exists between condylar guidance and anterior guidance and they therefore continue to establish the anterior guidance clinically according to patient comfort as well as aesthetic and phonetic demands. In other words, for any biomechanical system to function efficiently, there must be a certain amount of play. Joint play is greatly minimized whenever we iatrogenically close-pack the system at CR. Therefore in order to continue to function within the tight limits of available "buffer space" at CR, we must restrict jaw movement to essentially a verticalized pattern and/or provide steep anterior guidances as recommended by Hobo. Otherwise, we can expect articular remodelling to occur since more buffer space is necessary to accommodate a more horizontal chewing pattern.

Thus, although attempts to regain functional homeostasis via the "CR doorway" might be arguably sound when dealing selectively with healthy TMJs, this concept can be equally disastrous if applied indiscriminately to patients with histories of ligament laxity or other intra-capsular problems (Fig. 10). It is an unfortunate clinical fact that those patients in need of full-mouth rehabilitations rarely have normal, healthy TMJs.

Ironically, the biological acceptability of CR in clinical practice may be dependant specifically on the fact that it is not normally a functional jaw position. Since CRO schemes are situations whereby the dentition cannot be constructed to unload the joint, at best, both elements are required to share the burden of the masticatory forces generated at maximum intercuspation. Perhaps because of the re-distribution of masticatory load that occurs from the lateral to the more medial aspects of the condyle whenever CO is co-ordinated at CR, the craniomandibular articulation is subsequently more able to resist further stress since by deduction, there are probably larger amounts of residual undifferen-
tiated mesenchymal cells present in the medial pole. This would not be the case if CR was indeed a functional jaw relationship as some\textsuperscript{78, 104} have implied.

Another situation whereby CR techniques should be used with utmost caution is that of the chronic unilateral chewer. A significant proportion of the TMJ internal derangement patient population we see attest to habitual unilateral chewing. In order to maintain morpho-functional harmony, an individual who has been functioning exclusively on one side from childhood would tend to develop aberrant condylar forms. The ipsilateral (working side) condyle would be comparatively broader and more cylindrical in shape while the contra-lateral or translating condyle would generally be more rounded and more acutely angled in reference to the coronal plane\textsuperscript{78} (i.e., the capitulum is no longer at right angles to the plane of the ramus) (Fig. 5b, 11).

With this form of chronic jaw use, we know from our earlier discussions, the areas most loaded had a tendency to show degenerative change would be the medial aspects of the non-working condyle and the lateral aspects of the condyle on the chewing side. Should these patients require occlusal rehabilitation for whatever reasons, CR concepts are inappropriate because more load will be concentrated onto the already taxed medial aspects of the acutely angled non-working condyle even though the desired load transfer from the lateral to the more medial aspects of the joint on the opposite side might be achieved (Fig. 11). Patients with severe dental attrition and those who are chewing gum addicts must also be screened for adaptive medial pole changes before CR reconstructive techniques are prescribed.

Pantographic and gothic arch tracings exhibiting large amounts of immediate rather than the more usual progressive side shift during active lateral jaw excursions from Centric Relation especially after one has made certain that one has not obtained "sagged" bilateral condylar border recordings, as discussed by Levinson,\textsuperscript{122} are probably indicative of adaptive subarticular "soft tissue" build-up around the medial pole of the condyle.

Frontal TMJ tomography taken at maximum protrusion might also be helpful in detecting hard tissue changes in the medial aspects of the condyle can be detected using the Doppler auscultation, as previously discussed. Doppler auscultation will also allow the professional to easily and non-invasively diagnose partial disc displacement as well as to confirm whether he has successfully re-captured the disc during anterior jaw repositioning appliance therapy\textsuperscript{55, 123, 124} (Fig. 6).

Myocentric techniques\textsuperscript{141} on the other hand boast the ability to obtain a "more physiologic", neuromuscularly determined loose-
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Fig. 10a. A orthopantomogram of a 50-years old man with advanced degenerative joint changes. He had a history of joint clicking, locking, severe TMJ pain and recurrent headaches before undergoing a series of several extensive occlusal equilibrations under a dentist who believed in the CR concept. He never understood why he was recalled ever so often for ‘touch-up’ grinding procedures just when it seemed he got better. The dentist kept on removing the posterior occlusal prematurities which ‘reappeared’ without realizing that these were secondary to ongoing changes in the TMJs. He now experiences excruciating bone pain and rough crepitis each time he clenches his teeth.

Fig. 10b. Left and right transcranial TMJ views of the same patient when the intraborder space was regained with an acrylic intra-oral orthotic which was fitted over his lower dentition. He has been asymptomatic since, but notice the ‘peaking’ and ‘beaking’ of the condyles characteristic of advanced degenerative joint disease.

packed maxillo-mandibular relationship for oral rehabilitation. However, because the advocated technique of using transcutaneous electrical neural stimulation from the Myo-Monitor (Myo-Tronics Research Inc., Seattle, Washington, USA) to obtain this reference cannot distinguish between opening and closing muscle activity, the co-activated contraction of the inferior belly of the lateral pterygoid which happens to be a jaw-opening muscle in particular, will consistently result in a more anterior and inferior posture-dependent condyle position being registered.

This is an important consideration since electromyographic investigations have shown that the inferior belly is relatively silent at postural position and maximum intercuspation in asymptomatic individuals with healthy joint function. Although the validity of the Jankelson technique has been seriously questioned
Fig. 11a. A submental vertex view of a chronic right-sided chewer with TMJ dysfunction. Notice the more acutely angled left bi-polar condylar axis on the non-chewing side.

Fig. 11b. An orthopantomogram of the same patient. Although both joints are affected, you might appreciate that the vertical mandibular ramus measurement is slightly shorter on the left side, and the angle of the condylar neck is inclined more posteriorly. The coronoid process on the affected side will also be positioned more superiority in advanced cases. Notice the occlusal instability in the lower left quadrant. Medial pole remodelling can be seen on both condyles (left > right) since this particular patient also subluxates bilaterally.

on technical\textsuperscript{142} and neurophysiological\textsuperscript{143} grounds by independent evaluators, it is, perhaps, the variability\textsuperscript{144,145} of the myocentric that makes it less popular to restorative dentists since the coordination of the eccentric occlusal scheme now becomes an extremely laborious clinical task.

Although it has been enthusiastically reported that surgical repositioning of the maxillomandibular skeleton in patients with severe dentofacial abnormalities and concomitant TMJ symptomatology can help resolve or alleviate the latter, results from a recent survey\textsuperscript{146} suggest that this was an unpredictable undertaking. Some patients, in fact, developed TMJ symptoms after undergoing such surgery. The investigators postulated that overzealous seating of the condyle during sagittal advancement procedures in Class II situations may have predisposed previously asymptomatic patients to anterior disc displacements. Others\textsuperscript{147} have noted that intermaxillary fixation can produce significant histologic changes on the disc and articular surfaces of the TMJ.
Certain other orthognathic surgical procedures like the Vertical Subcondylar Ostectomy also subject the lateral aspects of the joint to greater loads and would theoretically tend to encourage anterior-medial disc displacements unless proper presurgical TMJ evaluation has been performed. The clinical significance of this, however, has yet to be established in a controlled clinical study.

Owing to the high incidence, a routine screening of all dental patients for TMJIDs is mandatory before any irreversible occlusal intervention is undertaken. The latter will be thoroughly discussed in a separate paper.

Clicking, locking and remodelling should thus be looked upon as adaptive phenomena occurring in response to a change in biomechanical loading of the craniomandibular articulation. It is important to emphasize that these adjustment processes will cease once the equilibrium between form and function is restored. However, having taken place, "the adjustive remodelling yields to the consequences", producing symptoms that may be appropriate for treatment. These include limited jaw opening and other forms of joint incoordination secondary to mechanical intracapsular disturbances, TMJ arthralgia, secondary muscle symptoms, occlusal instability, recurrent headache and a host of otolaryngological complaints. By his judicious modification of structure and behavior, the clinician can mediate positively in the patient's constant struggle along the dynamic gradient between orthofunction and dysfunction. Internal derangement, although highlighted in this discussion, is but a subcategory in the overall classification of Temporomandibular Joint Disorders. The TMJ, like all other joints in the body, is subject to a variety of afflictions. The most common group, however, seems to be lesions secondary to loading. The biomechanical loading that occurs during function and parafunction plays a significant role in the localisation, initiation and development of these intra-capsular tissue changes.

The purpose of this paper has been to identify relevant occlusal factors and certain patterns of jaw use which are likely to play a role in the pathogenesis of the Internal Derangement of the TMJ via recurrent microtrauma.

But unless serious efforts are made
i) to understand occlusion and its actual role in the biomechanics of the TMJ both in function and dysfunction,
ii) to discriminately identify only those morphologic occlusal parameters that have functional significance, and therefore develop more functional and more reliably predictive occlusal
indices,

iii) to differentiate between the various forms of TMJ disorders instead of conglomerating them under an all-inclusive TMJ syndrome,

iv) to treat men and women as separate groups in future TMJ epidemiological investigations, and at the same time conduct more longitudinal studies,

v) to employ sound orthopaedic principles in the evaluation of joint function instead of relying solely upon subjective patient reports,

vi) to qualify and quantify the wide intra and inter-individual variations in the adaptive capacity of the stomatognathic system at a histologic, neurophysiologic and/or biochemical level, correlative studies between occlusal factors and mandibular dysfunction will continue to produce misleading conclusions.

Despite the argument for the intermediary role of structural and physiological factors in this particular TMJ subpopulation, it must be emphatically stressed that a comprehensive view of the problem can only be attained via the concept of multifactorial etiology. Thus, the central question before the clinician in any particular symptomatic patient situation is "not which factor is involved, but how much of each is involved".5

SUMMARY

A hypothesis is presented as to how certain occlusal relationships and habitual patterns of jaw use may predispose an individual to TMJ internal derangements. Knowledge of diarthrodial joint biomechanics, in general, and the appreciation of close-packed positions of the TMJ, in particular, would not only provide the clinician with a greater discriminatory sense when diagnosing intracapsular problems but also help him to make better decisions and judgement about therapy. Popular treatment regimens, in particular those based upon the age-old Centric Relation concept, will be re-appraised.

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