Module 1 – Dental occlusion

Dental arch – Horizontal plane

- Mandibular arch: follow the buccal cusps of the molars and curve it to the incisors
  - This imaginary line follows a catenary curve
  - All cusps along this line are called “supporting cusps”
- Maxillary arch: determined by the mandibular arch
  - Supporting cusps of the mandible occlude with the central fossae and marginal ridges of the maxilla
  - Palatal cusps on the maxillary molars and premolars are also “supporting cusps” as they occlude with the central fossae and marginal ridges of the mandible
- Irregular curve in one arch = likely irregular on the other
- Ideal numbers and positions of contacts are rarely found

Dental arch – Lateral plane

- Posterior teeth have “tilt” → they are angled mesially
  - Matching forward tilts in both arches means adequate alveolar bone between roots
  - Also, marginal ridges are lined up so it is possible for a supporting cusp to occlude with 2 teeth’s marginal ridges. Called “cusp-embrasure occlusion”
- Anterior teeth have “torque” → they are angled facially
  - Although the central incisors appear vertical, their roots actually point distally
  - Tooth positions, torques, and anatomical crowns determine the horizontal and vertical overlap of the maxillary incisors over the mandibular ones
- Occlusal forces cannot be delivered simultaneously through the long axes of opposing teeth since their roots are not coaxial
- Curve of Spee
  - Mandibular teeth curves upwards, follows the natural curve of the mandible
  - The occlusal plane (yellow triangle) is defined by picking 3 supporting cusps which come in contact during occlusion. This occlusal plane is the same for both arches.
    - The Frankfort plane (red triangle) uses the inferior orbital rim and external acoustic meati
    - The Camper’s plane (green triangle) uses visual landmarks like the alar rim of the nose to the posterior tragus of each ear
    - Message: the occlusal plane is curved and unique as it is rarely parallel with the cranial planes

Dental arch – Frontal plane

- Anterior teeth up to first molars are quite upright
  - Maxillary centrals (11 and 21)
    - Overlap 30% of the mandibular incisors (called vertical overlap)
    - The incisal edges of 11 and 21 line up with the tips of 13 and 23
  - Maxillary laterals (12 and 22)
    - The laterals (12 and 22) are slightly shorter than centrals
    - Root tips are more depressed than the centrals or canines → this results in a depression called the incisive fossa
- Second and third molars are torqued increasingly → their occlusal tables lean inwards
- Curve of Wilson
  - Imaginary red line joining the occlusal tables of the teeth
  - Image on the bottom right is a distal view of the right first molars (16 + 46)
  - Left image = the molars are upright and CoW is flat (as it should be)
  - Middle image = torqueing of the maxillary first molars is possible during palatal expansion (orthodontic treatment). This increases the CoW
  - Right image = restorative treatment has lengthened the maxillary’s supporting cusp or the mandibular’s supporting cusp. As a result, the opposing molar has to deepen its fossa. This ends up increasing the CoW
Tooth contacts – Static

- **Intercuspal position**: maximum interdigititation between the maxillary and mandibular teeth
  - i.e. when the mandible is the closest it can be to the maxilla
  - Supporting cusp of the maxilla (lingual cusp) and mandible (buccal cusp) are in each others’ fossae
  - Mandible is then locked in a stable position determined by the teeth. Good for swallowing/communiting food
  - However, a good ICP should also include the placement of the condyles in the articular fossae. If the teeth are in ICP but the condyles are not centered + stable in the articular fossae, then it is not good ICP

- **During chewing**
  - Cusp slopes (1~2 mm) guide the teeth into maximum ICP and high occlusal forces happen in this narrow zone
  - The jaw remains stationary in ICP for about 200 msec, where high interocclusal forces are dissipated among teeth

- **Malpositioned teeth**
  - Short term: can intercuspate and be used comfortably
  - Long term: unacceptable, as it forces the mandible to habitually enter eccentric jaw postures during mastication

- **Cusp embrasure and cusp fossa contacts**
  - Supporting cusp tips should naturally contact flat opposing surfaces. This includes central fossae and marginal ridges of the opposing arch
  - There are many variations in cusp-embrasure contacts

- **Tripodization and bipodization**
  - Tripodization: when the supporting cusp occludes with the opposing tooth’s fossa, the cusp tip does not make contact with the fossa. Rather, the contact is made through the cusp inclines (the sides of the cusp tip). When tripodized, 3 cusp inclines are involved
    - Purpose: maximize tooth stability in ICP, deliver near axial forces to each tooth, and provide grooves to permit free jaw movement
    - Tripodization is rare naturally
  - Bipodization: supporting a cusp tip or fossa with 2 contacts instead of 3
  - Real life application
    - Multiple cusp fossa contacts are created during fabrication of prostheses articulated dental casts
    - If contacts on inclined planes are not mutual and there are <2 contacts on each molar, the teeth are not stable and can allow movement
    - Natural premolars are rarely tripodized, and can be tripodized by reconstructing in the scheme on the right

- **Natural intercuspal positions**
  - Don’t need to be symmetrical, but has to be bilateral and **heavily on the molars**
  - The contacts on the anteriors should be “feather light”, as complete absence of contacts → over eruption
  - In theory, 4+ contacts can be established per molar. This is achievable in restorative dentistry but is rare naturally

![Maxillary Right Mandibular Right](image)

<table>
<thead>
<tr>
<th>TOTAL NUMBER OF CONTACTS (YOUNG ADULTS 19-29 years, n=30)</th>
<th>MEDIAN NUMBER CONTACTS PER TOOTH (YOUNG ADULTS, n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIGHT PRESSURE</strong></td>
<td><strong>HARD PRESSURE</strong></td>
</tr>
<tr>
<td><strong>MEAN</strong></td>
<td>10.6</td>
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<tr>
<td><strong>SD</strong></td>
<td>4.2</td>
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</table>

<table>
<thead>
<tr>
<th>TOTAL NUMBER OF CONTACTS (ADULTS 30-69 years, n=61)</th>
<th>MEDIAN NUMBER CONTACTS PER TOOTH (ADULTS, n=63)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIGHT PRESSURE</strong></td>
<td><strong>HARD PRESSURE</strong></td>
</tr>
<tr>
<td><strong>MEAN</strong></td>
<td>7.4</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>4.6</td>
</tr>
</tbody>
</table>

- **Analysis of the study**
  - Older adults have fewer contacts at light pressures than young adults
  - On hard pressure, there is no significant difference
  - No difference in contacts on left/right sides
  - Older adults have fewer contacts on anterior teeth with light pressure than young adults
Dental arch – Cusps and grooves

- On the right is a schematic of the mandible (green) moving against the fixed maxilla (red)
  - Working side (green box) = supporting cusp tips move between the embrasures
  - Non working side (yellow box) = supporting cusp tips tend to collide
- In clinical dentistry, cusps and grooves can be fixed to reduce non working side collision
- Reshaping teeth requires attention to contacts in ICP, anterior protection and disclusion, understanding jaw movements, and anatomy specific to a patient

Tooth contacts – Dynamic

- Management of cuspal contacts during jaw movements is important in clinical dentistry
  - Often, anterior protected occlusion (central incisor + canine guidance) is used as it is simple to create
  - Group functioning contacts in multiple posterior teeth is much more difficult
  - Anterior guidance appears in 40~60% of people naturally
- Operator guided contact movements
  - Working side: protrusion, laterotrusion, lateroprotrusion
  - Non working side: mediotrusion
  - The operator tells the patient to start from ICP and move in a certain direction
  - This way, the operator can study the patient’s chewing movements in a systematic manner
    - The difference is we’re telling the patient to open slowly, rather than close (when chewing)

Dental arch – Protrusion

- Protrusion of the jaw is guided by the angles of the articular eminence (called the condylar guidance) and lingual surfaces of the maxillary teeth (called the incisal guidance)
- Disclusion = separation of the intercuspatation of teeth
  - Disclusion of the anterior teeth is most strongly affected by incisal guidance
  - Disclusion of the posterior teeth is affected by both incisal guidance and condylar guidance
- When condylar guidance is steep, it will disclude the posterior teeth irrespective of the incisal angle
- When condylar guidance is shallow, a steep incisal guidance is needed to disclude all posterior teeth
  - This produces an anterior protected occlusion. WTF does this mean???
    - When talking/eating/chewing, the maxillary molars will bang into the mandibular molars
    - This is because molars are so wide and there are so many cuspal variations
    - As a result, this will cause the molars to have premature wear
    - To protect the molars, the anterior teeth occlude first, and guide the molars into proper occlusion without “banging” them together. This is anterior protected occlusion
    - Then wouldn’t the anterior teeth be exposed to premature wear?
      - No, because the anterior teeth are further from the joint. Think about a doorstop. The doorstop close to the hinge (i.e. molars) will undergo a lot of stress whereas the doorstop closer to the doorknob (i.e. anterior teeth) won’t.
      - AKA mutually protected occlusion
  - A shallow condylar guidance increases risk of unwanted posterior contact/grinding. To prevent this, dentists like to create a steep incisal angle and establish anterior protected occlusion
- Real life application
  - If the Curve of Spee is flatter, then separation of the arches is less hindered and encouraged
  - In orthodontics and fixed prosthodontics, flat Curves of Spee are used to create anterior protected occlusion
  - A steep Curve of Spee will have more contact during protrusion, which is not favourable
    - Happens on backwards facing inclines on the maxilla and forward facing inclines on the mandible (yellow)
    - If these contacts are heavier than the guiding incisors or fully replace the function of the guiding incisors, they are protrusive interferences
Dental arch – Laterotrusion

- Laterotrusion of the jaw is guided by the articular eminence (called the condylar guidance) and maxillary non supporting cusps of the working surface (called the working side guidance).

- Condylar guidance
  - Working side: the condyle rotates in its fossa
  - Non working side: the condyle moves forwards, downwards, and inwards

- Working side guidance
  - In an anterior protected occlusion, the canine on the working side is the guiding tooth (like how incisors are the guiding tooth in protrusion)
  - However, cusps on the posterior working side can sometimes remain contact to result in group function guidance
    - Typically, group function guidance is 2 contacts on the working side (red and green) and 1 on the non working side (orange)
    - If these 3 contacts are lighter than canine guidance, then there is balanced occlusion
    - If these 3 contacts are heavier (or the only ones), then there is working/non-working side interference
    - The orange contact can sometimes be prevented by downward movement of the condyle on that side
    - In group function occlusion, combinations of canine/premolar/molar wear facets are often seen
      - The incisors can also provide some light guidance, but should not be the sole guidance tooth as it is too weak
      - Sliding contacts on single posterior teeth are also considered hazardous due to high lateral forces (molars are close to the jaw elevator muscles)

- Real life application
  - If the Curve of Wilson is flatter, then separation of the arches is less hindered and encouraged
  - In orthodontics and fixed prosthodontics, flat Curves of Wilson are used to avoid non working side contact

Dental arch – Other movements and overview

- Lateroprotrusion
  - Essentially the same as laterotrusion with added anterior movement
  - Both condyles move anteriorly with more translation of the condyle on the non-working side
  - Commonly seen in chewing, can involve edge-to-edge contact of the facial cusp tips which can lead to wear facets

- Mediotrusion
  - Happens to the teeth on the non working side during laterotrusion or lateroprotrusion
  - These teeth (non-working side) should not collide due to the harmfully large forces generated
  - Especially dangerous when these teeth become non-working side interferences, preventing working side contact

- Overview of movements
  - Laterotrusion = blue
  - Lateroprotrusion = black
  - Protrusive = red
  - Mediotrusive = green
  - The cusp tip starts in the fossa. There are 5 factors which determine whether that cusp will collide with the opposing cusp or go around it via the fossa:
    - Vertical disclusion
    - Where the cusps are placed*
    - Major groove directions*
    - Working side (rotating) and non working side (orbiting) condylar guiding paths
  - * = can be modified in prosthetic dentistry to minimize unwanted posterior contacts
Occlusal schemes

- **Jaw movements**
  - Different contact patterns appear during dynamic jaw movements
  - Contact patterns depend on tooth arrangement, dental anatomy, and condylar guidance (which can vary between left and right sides on one patient!)
  - Contacts can be seen in only the anteriors, only the posteriors, or on both

- **ABC occlusion**
  - Posterior teeth have 1 supporting cusp on the maxilla, and 1 on the mandible
    - Because there are 2 supporting cusps, there are 2 corresponding fossae/marginal ridges
    - This yields a “two row pattern” on the posterior teeth
  - Due to the 2 cusps, we get 3 possible points of contact, labelled A/B/C
    - A = inner surface of the maxillary facial cusp with the outer surface of the mandibular facial cusp
    - B = inner surface of the maxillary lingual cusp with the outer surface of the mandibular facial cusp
    - C = outer surface of the maxillary lingual cusp with the outer surface of the mandibular lingual cusp
  - Contacts during laterotrusion/mediotrusion
    - Working side: A alone or A + C, Non working side: B
    - Contacts can transfer from the working to the non working side teeth during chewing
  - Contacts during protrusion/retrusion
    - Contacts can occur between the anterior teeth only, posterior teeth only, or between both

- **Effect of orthodontic treatment on occlusion**
  - Position, orientation, and number of teeth can be changed during orthodontic treatment
  - Unless occlusal adjustment is carried out, occlusal anatomy of individual teeth does not change
  - Reshaping the arch will not reach the ideal occlusal contacts that are theoretically possible in ICP
    - The goal of orthodontics is to maximize correctly placed contacts and maintain a stable ICP
  - Ortho treatment usually results in a pattern of contacts resembling those seen in good natural dentitions
  - Mutually/anterior protected occlusion is also a goal, as it protects the posterior teeth

- **Effect of restorative treatment on occlusion**
  - When 1 tooth requires restoration: a cusp-embasure/cusp-marginal ridge is possible because other teeth will still be in cusp-fossa relationships (this is theoretically more stable due to tripodization)
  - When 2 opposing teeth require restorations: anatomy and occlusion can be completely reconfigured
    - Re-establishing natural cusp-embasure occlusion is an option, but cusp-fossa is now possible too
      - Cusp-fossa may be preferable because it allows tripodization
      - Goal: make the forces on the posterior teeth more axial than they were originally
      - Placing auxiliary grooves can make posterior contact even less likely during sliding movements
  - Mutually protected occlusion is a common prosthodontic practice. It’s easier than making natural group function
  - Clinically, there are no studies proving a prosthetic cusp-fossa occlusion is better or worse than a natural cusp-embasure occlusion. Both are viable.

- **Effect of dentures on occlusion**
  - Denture occlusions are designed to minimize instability and direct occlusal force to the edentulous ridges. This is achieved by balancing contacts and ramps placed on denture bases. Tooth form+location is thus critical to function
  - Denture teeth can have anatomical crowns or non anatomical ones (basically flat). Other teeth have single, linear rows of cutting edges
    - The clinician selects which forms of teeth should be used to increase denture stability
  - Lingualized occlusion: anatomical maxilla, non anatomical mandible. Maxillary crowns are then canted so that only the lingual cusps contact the centers of the flat mandible (which is placed right over the edentulous ridge)
  - Linear occlusion: non anatomical maxilla, single lined cutting edge mandible. Single line of contact ensures forces on the mandible are constant and directly downwards. “Cutting” action is more efficient than the “milling” action used in lingualized occlusion. Also, set the mandibular anteriors below the occlusal plane so that the teeth disengage through posterior guidance only. The idea is to minimize denture displacement

- **Effect of implants on occlusion**
  - Implants have narrow occlusal tables, central fossa loading, and low cusp inclines
  - Anterior guidance and lingualized occlusion are used to ensure loading only happens on the center of the implant
Module 2 – Clinical occlusal assessment

Occlusal examination

<table>
<thead>
<tr>
<th>Morphology</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Arch form</td>
<td>-Mandibular canine is in crossbite</td>
<td></td>
</tr>
<tr>
<td>-Tooth positions</td>
<td>-No canine guidance in laterotrusion</td>
<td></td>
</tr>
<tr>
<td>-Alignment</td>
<td>-Heavy group function in molar region</td>
<td></td>
</tr>
<tr>
<td>-Occlusal anatomy</td>
<td>-Impeded laterotrusion due to canine</td>
<td></td>
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<thead>
<tr>
<th>Physiological integrity</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Dental integrity (wear, fractures, cracking, crazing, restorations, mobility)</td>
<td>-Heavy attritional wear</td>
<td></td>
</tr>
<tr>
<td>-Periodontal integrity</td>
<td>-Fractures restoration in top left (not clearly visible in picture format)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Dentition may look unsound, but it is quite likely that the periodontium is healthy</td>
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<thead>
<tr>
<th>Articulation</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Between the dentition and TMJ</td>
<td>-RCP and ICP may have small discrepancies (“slide” of 1mm or less)</td>
<td></td>
</tr>
<tr>
<td>-Dentally determined jaw positions</td>
<td>-Large “slides” indicate a functional ICP which forces the condyles to function in unstable locations</td>
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<tr>
<td>-Retruded contact position (when the teeth first touch)</td>
<td>-Continuously stressing the condyles while on the slope of the articular eminence can lead to premature osteoarthritis</td>
<td></td>
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<tr>
<td>-Intercuspal position (when the jaw is fully closed)</td>
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<thead>
<tr>
<th>Habitual contacts</th>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Tooth wear patterns</td>
<td>-Canines have been worn flat</td>
<td></td>
</tr>
<tr>
<td>-Patterns may be due to habit or forced malocclusion</td>
<td>-Exposes the premolars to shearing forces, so additional wear on premolars is also seen</td>
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</tbody>
</table>

Protocol and armamentarium

- This examination is performed by a dentist to:
  - Visually assess the dentition to document the occlusion (tooth position, arrangement, contact pattern)
  - Measure occlusal features using a mirror, explorer, and perhaps a ruler/caliper
  - Record occlusal contacts between maxillary and mandibular teeth
  - Document and record tooth wear facets, fremitus and mobility
  - Visually assess dynamic tooth contact patterns in various voluntary and manipulated jaw positions

- Armamentarium
  - Examination kit, articulation forceps, articulating paper or ribbon (ideally 60~120 microns thickness)
    - See thicknesses on right →
  - 2x2 gauze
  - Triflow syringe and suction tip
  - Diagnostic casts if available

- Patient positioning
  - Advise the patient that the various tests and measurements are for documenting baseline data before treatment
  - Seat the patient in a mostly supine position with the head slightly elevated
  - If needed, compare contacts in ICP with patient in a supine vs an upright position since the contacts may differ
  - Assistance is desirable when holding the articulating forceps + patient’s jaw
Module 3 – Temporomandibular joint

Temporomandibular structure

- **Eminence and condyle**
  - Superficial, avascular, dense fibrous connective tissue covering the articular surfaces
  - Continuous with the fibrous layer of the periosteum
  - In fully grown adults, compact bone is directly under these layers
  - In growing children, the proliferative “pre-chondroblastic layer” is continuous with the “osteogenic layer” of the periosteum. The deeper “chondroblastic layer” contains mature chondrocytes. The deepest part is undergoing endochondral ossification via osteoblasts

- **Fossa**
  - Lamellar bone overlaid by periosteum
  - No cartilage as it is normally not load bearing

- **Disc**
  - Mostly collagen fibers with some fibroblast-like cells, fibrocytes, and chondrocytes
  - Fibers in the anterior and posterior thick bands run transversely
  - Fibers in the intermediate zone run anteroposteriorly
  - Anterior attachment: anterior margin of the preglenoid plane of the articular eminence
  - Posterior attachment: postglenoid tubercle
  - Attachment is strong laterally and medially

- **Retrodisal area**
  - Loose vascular connective tissue
  - Richly innervated by auriculotemporal nerve
  - The posterior part of the disc bifurcates
    - Superior retrodisal lamina: attached to the anterior face of the postglenoid process, bony and cartilaginous auditory meati, and fascia of the parotid gland
    - Inferior retrodisal lamina: attached to the posterior condyle. Comprised of compact collagen
  - Posterior attachment expands 3 dimensionally when the jaw opens widely

- **Synovia**
  - Has 2 compartments: upper and lower compartments
  - Made of thin inner linings of a few cells plus outer fibrous stromae which are vascularized, innervated, and contain lymphatics
  - Synovial fluid has vascular transudate and hyaluronic acid
  - 2 functions: metabolic and lubrication
    - Boundary lubrication – anteroposterior joint compartment shunting
    - Weeping lubrication – tissue shunting
• **Temporomandibular ligament**
  - Inner horizontal and outer oblique ligaments fuse into a **capsular** structure on the lateral wall of the TMJ
    - The “capsule” is a group of ligaments that include the 2 synovial compartments, medial+lateral discal ligaments, capsular ligaments, and temporomandibular ligaments
  - Ligaments are ideally suited to limit posterior and postero-inferior jaw movements. It can also resist lateral displacement
    - However, ligamentous restraint only happens at extreme jaw positions
  - **Frontal view**
    - Disc wraps around the condylar head (light yellow)
    - Condylar attachments (1 + 2) fuse with the capsule and lateral articular ligaments
    - Medial attachment (2) is **thicker and lower**
    - Lateral attachment (1) is **thinner and higher**. Perforations tend to occur in this zone

• **Muscles**
  - Inferior and superior heads of the **lateral pterygoid** (5, 7) are the most closely associated with articular mechanics
    - Inferior head (8) = inserts into the anterior fovea of the condylar head, originates on the lateral pterygoid plate
    - Superior head (6) = more variable. Tendons fuse in a complex which includes the fovea, tendinous attachment of the lower head, and anterior part of the articular disc. Originates on the roof of the infratemporal fossa
    - These muscles cause anterior movement of the condyle. With the superior head, it can also pull on the disc forward. The inferior head can pull the condyle downward.
  - The disc “sits on” the muscle like a foot, bound down to the perimysium of the upper head (4)
  - Anterior thick band of the disc (2), posterior thick band of the disc (1), intermediate segment (3), lateral pole of the condyle (9)

• **Clinical comments**
  - Variations in disc shape and condylar formation are common, and the disc can be displaced
  - Since TMJ articulations are load bearing, they are compromised in arthritides like rheumatoid or osteoarthritis
  - Retrodiscal area is highly vascular and innervated but highly susceptible to compression. This area is not for load bearing, and can cause pain when compressed
  - Synovial compartments can have effusions, inflammation, and adhesions
  - TMJ can be visualized by radiography (for bone) or MRI (for disc and synovia). Arthroscopy is possible, but limited
Clinical studies on TMJ structure and function

- Intercondylar Width (ICW)
  - Often expressed as bicondylar widths (distance between lateral poles). Various studies in different ethnic groups include mean bicondylar widths of: 119.97mm SD 6.48, 122.89mm SD 5.32, and 116mm SD 5.36.

- Age-Related Changes in Condylar Forms (7-17 Years)
  - Condylar size, horizontal-plane “anteversion” angles decrease during growth
  - The sagittal shape changes from round to oval (the round shape being common from 0-5 yrs)
  - Anterior “beaking” and some condylar flattening become evident in ages 10+yrs

- Deviations in Form (DIFs) in Young Adults 21-37 years
  - 39% of all joints showed mild to marked DIFs in all 3 joint components (fossa, disc and condyle)
  - Disc displacements found in 12% of the sample (confirming other studies)
  - Ellipsoidal shape is characteristic of a growing condyle, but may alter during early maturity
  - DIFs are likely adaptive responses to functional demands on the joint
  - DIFs are associated with an increased area of the temporal articular surface, suggesting the remodelling stimulus might be a more expansive jaw movement pattern

- Disc Position in Asymptomatic Subjects
  - 33% showed disc displacement

- Tensions and Deformations
  - At wide jaw opening, the largest stresses occur in the intermediate zone of disc from its middle to lateral aspect
  - i.e. when opposing articular-eminence and condylar surfaces are not co-planar
  - Von Mises stresses in the disc are larger than in the articular layers of the fossa and condylar head
  - Maximum principal stress is almost exclusively compressive in these cartilage layers. Disc showed tensile and compressive stresses. Largest strains in disc occurred during loaded jaw closing movements. The loaded disc deforms more than the softer cartilaginous layers (where forces are transmitted directly to the underlying bone).
  - In the disc, the forces can propagate parallel to the articular surfaces, causing large deformations and large local tensions. Although disc is susceptible to such deformations it needs to be stiffer than the cartilages. It is primarily stressed in shear, spreading compressive stresses to wider areas on the fossa and condylar cartilage.

- Disc Viscoelasticity Direct Bench Tests
  - The disc is 75% water by wet weight, 62% type I collagen and 3% GAGs by dry weight
  - It shows a biphasic mechanical behavior, and is softer and more permeable than normal human articular cartilage
  - The central region is stiffer (measured when the fluid component is stationary) than the anterior or posterior bands (which are softer and more permeable). Fluid pressurization of the disc plays a significant role under dynamic load

- Disc Structure and Biomechanics
  - Proteoglycans contribute to viscoelasticity (mostly in central region)
  - The disc is avascular, obtaining nutrients from the synovial fluid and blood vessels in posterior bilaminar zone
  - Hyaluronic acid from the synovium is important for lubrication
  - The disc is subject to compression, tension and shear (with regional variation). During tension, the coiled collagen “waves” straighten, the fibres extend and become load-bearing. As the network deforms, fluid flows outward from disc as the fibres rearrange. The largest stresses (during clenching) occur in the central region and lateral part of the disc.
  - The disc’s collagen content increases with age but its water content remains the same, therefore there is greater elasticity in older discs

- Effect of an Occlusal Appliance
  - Significant anteroinferior and rotational movements of the condyle occur when an appliance is inserted between the teeth. But the disc does not always move anteriorly
Temporomandibular joint function

- Open/close cycle
  - When the jaw opens, both parts of the lateral pterygoid contract (seen in red)
    - The disc rotates under the eminence
    - The condyle rotates under the disc
    - The disc and condyle are compressed due to tension from the closing muscles
  - During jaw closure, the lateral pterygoid relaxes (blue)
    - The disc and condyle are still compressed due to tension from the active closing muscles
  - The shape, synovial lubrication, and appositional compression all contribute to help the disc remain between the condyle and eminence
    - https://www.youtube.com/watch?time_continue=31&v=4I03gAQwA1o
    - https://www.youtube.com/watch?time_continue=36&v=73aR60096ME

- Opening the jaw about the midline
  - Red lines in the left image represent the changing helical axis from the start of opening until the end of opening
  - As the jaw opens, the condyles translate forward while opening, as depicted by the blue lines

- Opening the jaw away from the midline (laterotrusively)
  - The picture depicts a right sided chewing stroke
  - Opening phase: both condyles move forward (same as midline opening)
  - Closing phase: the right condyle translates back into the fossa before the left. This causes the jaw to swing towards the right side. From this point on, the right condyle simply needs to rotate to allow the left condyle to return to the fossa.
    - Rotation that the right condyle underwent: pitches parasagittally \(\rightarrow\) rolls coronally \(\rightarrow\) yaws horizontally

- TMJ abnormalities
  - Clicking, crepitus, disc displacement (with and without reduction), deviations in jaw motion, pain
  - Motion of condyles requires sophisticated technology, therefore it’s rarely done in general practice

Biomechanics and dysfunction

- Disc mechanics
  - The disc is viscoelastic. It is less stiff under supero-inferior compression and more stiff in antero-posterior tension. When pressed, the disc elongates
  - The disc is subject mostly to supero-inferior forces
  - The intermediate part of the disc has fibers running antero-posteriorly. Therefore, they withstand forces in the antero-posterior direction. Fiber crimping here suggests they can elongate this axis
  - The anterior and posterior part of the disc has fibers run transversely (left/right). These fibers fuse with the capsular ligament. If the attachment on the lateral side of the capsule is deficient, it can cause anteromedial displacement of the disc (seen in many cases of disc derangement)
  - Even if the jaw is closing and the condyle is moving, the disc is still under stretching forces. This suggests that in any dynamically loaded state, the disc and capsule are under tensile force and hence elongates
  - Presently, it is not possible to measure disc mechanics in living humans
• Disc derangement
  o The derangement of discs depends on the patient’s joint shape, tissue properties, occlusal deformities, and functional acts made by the patient
    ▪ For example, patients with severe anterior overbites must adopt posterior chewing trajectories
  o Condylar deviation in articular form (DIF) is one factor that can lead to disc derangement. It studies the abnormal shapes of the condyle
    ▪ It can commence during adolescence, and are evident in young adults
    ▪ Articular stresses and movements during growth are likely responsible for the various morphologies of the condyle
    ▪ Examples of some condylar DIF’s can be seen on the right
    ▪ Presence of a DIF does not mean their jaw is malfunctioning
      ▪ Many people have DIF’s and don’t know/notice
      ▪ 39% of TMJ’s show mild~moderate DIF’s in all 3 components (seen on the right)
      ▪ 12% of TMJ’s had disc displacement, with more being in women
  o Condylar horizontal/vertical orientation can also differ
    ▪ Blue line = long axis of the cranium
    ▪ Red line = long axis of the condyle
    ▪ Angle between red and blue = horizontal condylar orientation. It is typically 0~50 degrees
    ▪ The same measurement can be done when viewing the condyle frontally. This measures the vertical condylar angle, which is typically -10~35 degrees
    ▪ Right and left side angulations may not be the same
    ▪ Functional manifestations of these differences is unclear, but suggests that intra articular mechanics must also differ
  o Measuring disc position
    ▪ Currently, it is not possible to measure disc mechanics, but it is possible to visualize disc positions by taking MRI’s of the patients’ TMJ in a static state
    ▪ The images of the disc are used to assess whether the disc is normally positioned, partially displaced, or completely displaced (with or without reduction to a more normal position during jaw opening)
    ▪ “Normal” disc position with jaw closed
      ▪ Start from the condyle’s center
      ▪ Draw 1 line going from the condyle center to the Frankfort Horizontal plane (see page 1 for definition of FH plane)
      ▪ Draw a second line going from the condyle center to the junction of the posterior band + bilaminar zone
      ▪ Angle of <10 degrees between these lines is considered normal
    ▪ “Abnormal” disc position
      ▪ Depends on image plane of section and number of sections available
      ▪ Standard protocols use oblique sagittal and oblique coronal orientations
        ▪ Perpendicular and parallel to the long axis of the condyle
        ▪ Many sections/pictures are needed in each orientation. This is because anterior displacement may be seen in the lateral sagittal section, but it may be normal when a medial sagittal section is taken
          ▪ This kind of displacement can begin early in life
          ▪ It is found in about 30% of young adults without symptoms of dysfunction
          ▪ The displacement is often partial and unilateral, and the disc usually reduces during jaw opening
      ▪ 95% diagnostic accuracy using this method
Module 4 – Jaw movements

Border movements and positions

- Jaw border movements
  - The jaw can move within a set boundary. This boundary is set by the bone, ligament, muscle, and tooth anatomy
  - The border movements can be defined by manipulating a relaxed jaw
  - On the right, the red at the top signifies condylar movement. The red on the bottom signifies the 3D boundaries of the midline of the mandibular incisors
    - This 3D figure is called the Posselt figure
    - Note: path shown for condyles are simplified. They vary more in real life
    - 3D border movements are rarely measured in routine practice, rather key positions are measured and recorded as necessary
  - Border movements can be restricted in articular, muscle, or dental abnormalities

- Posselt approach: Lateral view
  - Remember this is the location of the mandibular incisor’s tip
  - Start from habitual resting position (HRP). This is not a border
  - ICP = intercuspal position
  - RCP = retruded contact position. When opening the jaw, this is the last point at which the mandibular tooth makes contact with a maxillary tooth
    - Sometimes, ICP can be the same as RCP naturally. In treatment, it is the clinician’s goal to make ICP = RCP
    - ICP and RCP can vary by several mm in severe malocclusion
  - CR = centric relation. Part of jaw opening where the condyles are stationary. At the end of CR, the condyles pop out of the fossa to allow further jaw opening. Usually 15~20 mm
  - PG = protrusive guidance. Part of protrusion where the mandibular incisors can still be guided by the maxillary incisors. The incisors remain contact during this path
  - MP = maximum protrusion
  - MO = max open

- Posselt approach: Frontal view
  - Laterotrusion of the jaw is normally guided by the canines
  - Laterotrusion is measured up until the canines are edge-to-edge
  - In this image of the Posselt approach, it shows symmetry. In real life, the shape varies greatly and is often asymmetrical as it depends on tooth anatomy
  - Remember: in laterotrusion, working side simply rotates while the non working side tracks forward, downward, and inward

- Dawson method: Lateral view
  - Upwards and forwards compression is applied on the condyles, so that the condyles seat in their fossae, on the center of their articular discs
    - Reduces condyle from moving posteriorly or anteriorly, off the articular fossa
  - May form a different border movement than the Posselt approach
  - ICP and RCP = there may still be a difference, but usually less than Posselt
    - In this image, ICP coincides with RCP
  - CR = begins from the same position as Posselt

- Malocclusions
<table>
<thead>
<tr>
<th>-Teeth in ICP -Condyle in fossa</th>
<th>-Teeth in ICP -Condyle not in fossa</th>
<th>-Teeth not in ICP -Condyle in fossa</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Normal and ideal" /></td>
<td><img src="image2" alt="Occlusion may appear normal on clinical exam" /></td>
<td><img src="image3" alt="Closing from RCP to habitual ICP would displace the jaw forward" /></td>
</tr>
</tbody>
</table>
Centric relation:
- **Centric relation**: The maxillomandibular relationship in which the condyles articulate with the thinnest avascular portion of their respective discs with the complex in the anterior-superior position against the shapes of the articular eminences. This position is independent of tooth contact. This position is clinically discernible when the mandible is directed superior and anteriorly. It is restricted to a purely rotary movement about the transverse horizontal axis.
  - CR registration is important in occlusal diagnosis and therapy
  - When new occlusal relationships are made (ortho, prosthodontic, denture), **CR is the reference position for the new RCP, which coincides with the new ICP**
  - CR may also be the point of reference in mounting dental casts in an articulator
  - CR must be reproducible with multiple appointments with the patient
  - Changes to the vertical dimension of occlusion can be made because CR is a simple hinge-based motion

- **Myocentric relation**: a conceptually different position. This is when the jaw is relaxed and electrical stimulation makes the jaw muscles clench the teeth together.

How to ensure proper condyle seating so CR can be measured:
- **Dawson bimanual/monomanual method**
  - Manipulation of the mandible in a relaxed patient
  - Place the thumb on the mental area and fingers on the mandible’s lower border
  - Manipulate the jaw to make sure the condyles are seated in the fossae
  - Then, torque the mandible with the fingers and thumbs (open/close/rotate)
  - Never forcefully retrude the mandible. The term “retruded” in this context simply refers to not protruded

- **Lucia Jig method**
  - Incisal clenching on the Lucia Jig without protruding the jaw
  - Activates the masseter and medial pterygoid but not the temporalis → upwards and forwards force → ensures condylar seating

- **Huffman leaf method**
  - Patient bites down on the stack of leaves
  - Leaves are removed until minimal posterior tooth separation is obtained
  - When this is achieved, tell the patient to clench → seats the condyles
  - Disadvantage: when the leaves are not oriented properly and the bite force is excessive, it will distalize the condyles

How to deprogram the patient to get an accurate CR reading:
- Patients with malocclusion will subconsciously force their condyles out of the fossa when they’re biting down, like a reflex
- This hampers the ability to get an accurate CR
- So, you have to “deprogram” this muscle memory in the patient
- Deprogramming can simply be done by using a spacer (cotton roll, Lucia Jig) between the anterior teeth before the CR record is taken

How to record and preserve the static CR position, once condyle seating and deprogramming are established (i.e. how to record the patient’s static CR so you can transfer it to your articulator):
- **Articulating ribbon**
  - Not ideal because the cusps inclines can deflect the position of the condyles when closing/opening
- **Interocclusal materials (wax/polyvinyl siloxane)**
  - More ideal, wedge this between the occlusal surfaces and make sure the teeth cusps don’t touch
  - Material should be fluid or soft to prevent jaw deflection, but set rigid to avoid distortion upon removal

- **Lucia Jig** (for difficult cases)
  - Used in combination with an interocclusal record (like wax/polyvinyl siloxane)
  - Same method as before, but this time, insert an articulating ribbon beneath the Lucia Jig to record mandibular incisor position when retruded (in CR)
  - Apply the interocclusal material and tell the patient to bite down, guiding their lower incisors to the previously marked position. This ensures a bite registration of the patient in CR.
## Module 5 – Jaw muscles

### Jaw muscle structure

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Temporalis</th>
<th>Masseter</th>
<th>Medial pterygoid</th>
<th>Lateral pterygoid</th>
<th>Digastric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of contraction</td>
<td>-Complex contractions: can contract parts of the muscle selectively, depending on the task</td>
<td>-Simple contractions to open/rotate the jaw and move it laterally</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence of spindles</td>
<td>-Has muscle spindles, which indicates presence of stretch reflexes</td>
<td>-CNS reaches these muscles via alpha gamma coactivation</td>
<td>-Can be sensitive intraorally (anterior border) and extraorally (inferior border)</td>
<td>-Cannot be palpated directly, and complex as it connects to the condyle and disc</td>
<td>-Rarely myalgic, as with all infra-mandibular muscles</td>
</tr>
<tr>
<td>Muscle pain (myalgia)</td>
<td>-Can be sensitive intraorally medial to the coronoid process, but is often confused with the lateral pterygoid as these structures are so close together</td>
<td>-Can be sensitive below the zygoma and in front of the condyle (deep masseter)</td>
<td>-Can be sensitive intraorally (anterior border) and extraorally (inferior border)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure</td>
<td>-Bipennate</td>
<td>-Multi layered</td>
<td>-Heavily pennated</td>
<td>-2 heads: superior and inferior which differ in size</td>
<td>-Retracts the mandible</td>
</tr>
<tr>
<td></td>
<td>-Very tendinous near its insertion on the coronoid</td>
<td></td>
<td>-Very tendinous along zygomatic arch and deep central region</td>
<td>-Both heads mostly function as synergists (does the same function)</td>
<td>-Contribution to jaw opening diminishes with further opening</td>
</tr>
<tr>
<td></td>
<td>-Extensive central aponeurosis (see frontal)</td>
<td></td>
<td>-Very powerful</td>
<td>-Very tendinous at their intersection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Closely attributed to the lateral pterygoid</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>-Anterior = greatest cross sectional area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Anterior temporalis can insert as far down as the retromolar triangle (red)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Therefore, pain in the maxillary buccal sulcus is likely due to the anterior temporalis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Function</td>
<td><strong>Anterior</strong> -Pulls inner coronoid upward, forwards, and slightly laterally</td>
<td><strong>Superficial fibers</strong> -Pulls ramus upwards and forwards</td>
<td><strong>Superior</strong> -Pulls condyle forward and medially</td>
<td><strong>Anterior</strong> -Strongly backwards, slightly downwards</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Middle/posterior</strong> -Upward, backwards, and slightly laterally</td>
<td><strong>Deep fibers</strong> -Pulls ramus upwards and outwards</td>
<td><strong>Inferior</strong> -Pulls condyle forward and medially</td>
<td><strong>Posterior</strong> -Contracts with anterior belly</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Works with anterior temporalis</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Jaw muscle function

- **Muscles**
  - Maximum strength is determined by their cross sectional size
  - Muscles are larger in brachycephalics than dolichocephalics

- **Bite force and rest positions**
  - **Habitual rest position**: the muscles are always contracting at a low level, which brings the incisors together to 1~3 mm
    - Can vary with factors like alertness, apprehension, and relaxation
  - **Relaxed rest position**: the muscles are completely relaxed, and the jaw is held by passive muscle tensions. This is 5~12 mm
  - **Maximum bite force**: when the incisors are separated by 12~25 mm, the jaw can contract with the most force

- **Clinical comment**
  - Contraction activity of muscles like masseter and temporalis can be done simply by placing a finger over the muscles
  - Activity of the medial/lateral pterygoid requires electromyography
  - In general, palpation is not a very reliable method in diagnosing articular or muscle related issues
  - **Jaw stiffness**
    - The antagonist muscles contract at the same time as the jaw muscles (co-contraction)
    - This is involuntary, and could be due to pain or the body’s method of minimizing further pain

- **Muscle forces**
  - **Black dot** = jaw’s center of mass
  - **Red line** = force on the jaw due to the muscle
  - **Blue line** = perpendicular to the red line, it is the axis in which torque is applied
    - Torque is determined by muscle force and perpendicular distance from the axis
  - When multiple muscles contract, the forces and torques sum
    - $\Sigma$ forces and torques = 0 $\rightarrow$ static equilibrium (like tooth clenching)
    - $\Sigma$ forces and torques $\neq$ 0 $\rightarrow$ jaw movement, shearing forces at teeth (like chewing)
  - **Jaw muscles are activated bilaterally, never in isolation**
    - However, this does not imply that there is symmetrical contraction
    - Unique pattern generates a bite force without jaw movement
    - Notice how clenching (static) and chewing (dynamic) patterns involve different muscles even though the same teeth contacts are involved
    - A particular dental act is associated with a likely pattern of muscle contraction

- **Why do we study jaw muscles**
  - Estimates the probable distribution of force among the teeth and TMJ
  - Pinpoints which muscles are likely to be painful with excessive use
Jaw muscle actions

- Jaw opening (3 stages)
  - Contraction of the anterior digastrics
    - Retrudes the jaw
    - Happens in a hinge-like motion because the condyles are seated and braced in the articular fossae
  - Contraction of the inferior lateral pterygoids
    - Causes jaw protrusion which also moves the jaw downwards due to guidance by the articular eminence
  - Contraction of the anterior digastrics, superior lateral pterygoids, inferior lateral pterygoids
    - Only needed when the jaw is fully opened
  - As the jaw reaches max opening, the jaw actually begins to close due to passive forces from the closing muscles

- Unilateral tooth clenching (1 stage)
  - Assume clenching on left side
  - Contraction of the left temporalis
    - Lifts the jaw into tooth contact and pulls to the left
  - Contraction of the right superficial masseter
    - Lifts the jaw into tooth contact, pulls to the right, and moves the jaw slightly forward
    - The left/right pull co-contraction of the temporalis and masseter contributes to stability
  - Contraction of the right medial pterygoid
    - Lifts the jaw into stable left sided tooth contact because its line of action passes inside the triangle formed by the bite point and the two condyles
    - Increases the bite force without any loss of stability
  - Contraction of other muscles: left deep masseter, left superficial masseter, right lateral pterygoid

- Intercuspal clenching
  - Begins with bilateral activation of the superficial masseters alone. These muscles supply most of the clenching force, but tends to draw the jaws forward
  - Eventually, all of the elevator muscles are contracted together to stabilize and increase clenching strength
  - All of the muscles give a resultant vector force which is perpendicular to the occlusal plane

- Chewing
  - Dynamic involvement of muscles to open the jaw, close it (laterally towards the chewing side), compress the food bolus, shear medially through the intercuspal position, and begin opening again
  - In clenching, stability was the goal. In chewing, shearing is the goal, not stability
  - Diagram on the right
    - ws = working side
    - bs = balancing side
    - Vertical parts = contributes to vertical movement of the jaw
    - Triplet 1 = upward + lateral movement
    - Triplet 2 = upward + medial movement
Jaw muscle assessment

- Muscle provocation – 2 methods
  - Voluntary activation: the clinician tells/assists the patient in moving the jaw into certain positions to test for specific muscles. Clinician must be familiar with which muscles are activated with a certain test. It can be complicated by painful muscles or a painful TMJ
  - Palpation: can be done for most muscles, but not the lateral pterygoid or some parts of the medial pterygoid. Also, it is hard to separately palpate the digastric, geniohyoid, and mylohyoid muscles. Using this method is also subject to pain, but bilateral testing identifies if the pain is due to palpatating too hard or pathology of the patient

- Masseter

<table>
<thead>
<tr>
<th>Anterior and posterior borders of the masseter</th>
<th>Central region of the masseter</th>
<th>Anterior part can be palpated both intra and extra orally</th>
<th>Deep tendinous origin on zygomatic arch can be reached intra orally via the vestibule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep masseter can be palpated via a finger’s breadth anterior-inferior to the condyle</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Temporalis

<table>
<thead>
<tr>
<th>Extra oral palpation can be done with the middle and posterior temporalis and the superficial anterior temporalis</th>
<th>Deep anterior temporalis and its mandibular insertion can be palpated intra orally on the medial side of the coronoid process and towards its tip</th>
<th>Swinging jaw to the same side may be helpful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandibular insertion can be reached extra orally</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hook the fingers around the lower mandible</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Medial pterygoid

| Mandibular insertion can be reached extra orally |
| Hook the fingers around the lower mandible |
| Anterior region can be reached intra orally deep on the lingual side of the mandible and followed up for a short distance deep to the pterygomandibular raphe |

- TMJ

<table>
<thead>
<tr>
<th>Intrameatal pressure</th>
<th>Pressure over the lateral condylar pole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving a finger breadth anteriorly will palpate the deep masseter</td>
<td></td>
</tr>
</tbody>
</table>
Module 6 – Mastication

Neuromuscular control (4 regions in the nervous system responsible for controlling mastication)

- **Peripheral nervous system**
  - **Components**
    - **Mechanoreceptors in** | **Relays signals via** | **Type of information sent**
      - Skin and mucosa | CN5 | Primarily sensation, but some proprioception
      - Joint (articular) | CN5 | Jaw proprioception and movement
      - Jaw closing muscles | Mes5 | Sensory information sent monosynaptically via muscle spindles
      - Periodontium | CNS, Mes5 | Senses mechanical load on the teeth, but varies on tooth type

  - How the periodontal mechanoreceptors relay sensory information

<table>
<thead>
<tr>
<th>Mandibular molars</th>
<th>Mandibular incisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>High threshold</td>
</tr>
<tr>
<td>Direction of force detected</td>
<td>Axially, distally, lingually</td>
</tr>
<tr>
<td>Range of forces detected</td>
<td>&quot;Non saturating&quot; receptors</td>
</tr>
<tr>
<td>Reason for difference</td>
<td>Works with high forces like mastication</td>
</tr>
</tbody>
</table>

- **Functions**
  - Sensation (exteroception), proprioception, nociception, feedback motor drive
  - **Note**: tooth loss eliminates periodontal mechanoreceptors → decreased dental perception

- **Brainstem**
  - **Components**
    - CNS brainstem sensory nuclear complex, solitary tract nucleus, motor nuclei for CN 5,7,9,10,12
    - Also closely related to inter-trigeminal nucleus, supra-trigeminal nucleus, parts of medial/lateral reticular formation
  - **Functions**
    - **Afferent**: relays afferents to higher brain centers
    - **Efferent**: relays efferents to the orofacial muscles, generates + modulates brainstem reflexes, provides central pattern generators (CPGs) for chewing and swallowing
  - **Involuntary reflexes** controlled by the brainstem (diagram on right)
    - Red arrow = excitatory, Blue arrow = inhibitory, Arrow head = synapse
    - **Note**: these are transitory reflexes, they do not explain muscle contraction during persistent orofacial pain

<table>
<thead>
<tr>
<th>Jaw closing reflex</th>
<th>Jaw opening reflex</th>
<th>Jaw unloading reflex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monosynaptic</td>
<td>Disynaptic</td>
<td>Disynaptic</td>
</tr>
<tr>
<td>(single arrow to closing muscle)</td>
<td>(2 arrows to opening muscle)</td>
<td>(this is the same reflex as jaw opening, but in a specific scenario)</td>
</tr>
<tr>
<td>Postural control</td>
<td>Strong stimulation of the mouth will cause a flexion withdrawal response (opening of jaw)</td>
<td>Happens when the object you’re biting on suddenly fractures</td>
</tr>
<tr>
<td>of the mandible</td>
<td>-Inhibits closing muscles</td>
<td>-Eg: when a candy fractures when biting hard, the jaw immediately unloads the force to prevent teeth from colliding</td>
</tr>
<tr>
<td>during locomotion</td>
<td>-Stimulates opening muscles if stimulus is intense enough</td>
<td>-Body will detect sudden change in muscle spindle and periodontal sensory input</td>
</tr>
<tr>
<td>-Inactive when the jaw is resting</td>
<td>-Reflex is to inhibit the closers and activate the openers</td>
<td>-Co-contraction of openers before object fracture will help arrest jaw motion, making opener activation unnecessary</td>
</tr>
</tbody>
</table>

- **These reflexes are not associated with temporomandibular disorders**
  - It is not the muscles that cause TM disorders, rather the muscles become painful secondary to TMD’s
  - Pain adaptation hypothesis: TM disorders cause muscle inhibition as the body tries to minimize the pain
Subcortical regions

Components
- Thalamus, basal ganglia, cerebellum, red nucleus, reticular formation

Functions
- Sensorimotor integration and motor learning
- Has transaxial CNS connections
  - Motor efferents
  - Ensures bilateral (but not necessarily symmetrical) muscle activation of more than 1 muscle
  - This is why it is impossible for one to voluntarily activate just one jaw muscle on one side
- Access and modify the activity of the brainstem’s CPG
  - See diagram on right
  - I have no idea what it means either
  - The CPG takes part in semi-automatic and automatic rhythmical jaw movements

Diseases related to this region
- Sleep bruxism: CPG and other subcortical motor activity like the limbic system are likely responsible
- Impaired mastication in Parkinson’s: imbalance of dopamine and changes to basal ganglia activity
- Oral dyskinesia: imbalance of dopamine and changes to basal ganglia activity
- Other impaired jaw motor control: imbalance in Ach, GABA, glutamine, serotonin, vasopressin, catecholamines, and opioids

Cerebral cortex

Components
- Primary face motor cortex, face primary somatosensory area, premotor cortex, supplementary motor area, cortical masticatory area, anterior cingulate gyrus, and the insula

Functions
- Note: the list below are the functions for just the primary motor cortex (M1), cortical masticatory area (dotted), and primary somatosensory region (lines)
  - Efferent: mastication, fine motor control of jaw and tongue, swallowing
  - Afferent: refines cortical sensory input to shape appropriate motor responses, particularly during preparation and manipulation of a food bolus. This is called sensorimotor integration
- Other areas generate different jaw movements, but not in our scope

Neuroplasticity (motor learning)
- The ability or inability of a patient to adapt to dental alterations like tooth loss, orthodontic changes, or prosthodontic changes
- The sensorimotor cortex is able to learn and adopt new chewing patterns and behaviours
- Examples of maladaptation and sensorimotor dysfunction
  - Embouchure dystonia: inability for musicians playing woodwind/brass instruments to coordinate the complex tongue, jaw, and facial muscle movements required to play the instrument
  - Dysphagia, dysarthria, and impaired chewing due to stroke
- Example of adaptation
  - When teeth are removed and implants are placed, the periodontal mechanoreceptors are removed. This eliminates the force sensation and discrimination of that area of the jaw.
  - Following implant therapy, neuroplastic changes can allow osseoreceptors to provide bite force sensation and tactile discrimination without periodontal mechanoreceptors
Mastication

- **Chewing patterns**
  - Varies depending on the person, bolus size, and consistency
  - Bolus is placed unilaterally and moved randomly side to side
  - Asynchronous contraction \( \rightarrow \) produces cyclical movements and shear forces
  - Each cycle lasts 0.7~1 sec
  - Tooth contacts tend to occur on cuspal inclines within 2mm of the intercuspal position

- **Chewing cycle (for a right sided stroke)**

<table>
<thead>
<tr>
<th>Midline opening</th>
<th>Early closing</th>
<th>Final power phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both condyles move forward and downward</td>
<td>-Working side condyle returns to its fossa first</td>
<td>-Non working condyle returns to its fossa</td>
</tr>
<tr>
<td>Jaw rotates open</td>
<td>-Mandible rotates in a closing direction towards the working side</td>
<td>-Jaw continues to close, now closing on the non working side</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Tooth move into and through the intercuspal position</td>
</tr>
</tbody>
</table>

- The **non working side’s condyle** is the most compressively loaded and its joint space narrows due to the lack of a bolus on this side
- Lower incisor point movement
  - Useful for imaging the chewing cycle shape
  - SO = slow opening, FO = fast opening (near max. opening)
  - FC = fast closing, SC = slow closing (compression of bolus)
  - SC \( \rightarrow \) SO depends on thickness and hardness of the bolus. As the bolus gets chewed more, the teeth get closer to each other with every bite
  - If the bolus is thin (like when chewing gum), the jaw pauses in ICP for 200 msec before opening again

- **Chewing cycle variations**
  - Tough foods are associated with a wider pattern of lower incisor point movements and the opposite for soft foods
    - Picture on the right \( \rightarrow \) this is a frontal view of incisor point movements
    - Top left = tough food, top right = soft food
  - 12% of the population (mostly denture wearers, prognathic subjects, and children) will have a reversed trajectory
    - Represented by the bottom left and bottom right incisor point movements
    - Major occlusal interferences can alter motion trajectories near the ICP
  - Class 3 malocclusion patients will have a predominantly vertical chewing stroke

- **Power stroke – 3 stages**
  - Buccal slow closing phase (left image)
    - Bolus gets sheared between inner maxillary buccal cusps and outer mandibular buccal cusps
    - Jaw rotates around working side condyle as the non working side condyle slides back
    - Wear pattern on maxilla is shown in red
  - Intercuspal position (middle image)
    - Power stroke usually ends here
  - Lingual slow opening phase (right image)
    - Doesn’t always happen, but is common
    - Bolus gets sheared between inner maxillary lingual cusps and inner mandibular buccal cusps
    - Non working side condyle rotates as the working side condyle begins to move forward
    - Wear pattern in maxilla is shown in green
Attrition

- **Human attrition**
  - One factor contributing to tooth wear (others being erosion, biocorrosion, and abfraction)
  - Greatest in hunter-gatherer populations, and less in industrialized populations
  - Wear is progressive and visible on the occlusal and interproximal surfaces
  - Other related features: mesial drift of teeth, continuous tooth eruption, lingual tipping of anteriors
  - The attrition and loss of occlusal cusps can be seen as beneficial
    - The cusps initially help guide the teeth into proper occlusion
    - Over time, the cusps flattening gives more surface area for efficient chewing to take place
    - More axially aligned forces can be generated, turning teeth into “pestle-and-mortar” systems

- **Attrition patterns**
  - **On supporting cusps**
    - Wears down on buccal and lingual incline
  - **On non-supporting cusps**
    - Wears down on inner inclines only
  - This eventually turns into a reversed curve of Wilson near the front up to the first molar, but the normal CoW is retained in the posterior molar region
    - Diagram: shows occlusion of teeth 16 and 46
    - A turns into B with attrition
  - Note: curve of Spee is unchanged. However, there is usually no anterior guidance due to major wear of the anterior teeth

- **Helicoidal wear patterns**
  - Molar 1 wears down the fastest and has the reversed CoW
  - Molar 2 is the transitional area
  - Molar 3 does not show wear patterns because of their buccolingual inclination, late eruption, less maxillary overjet, and less mandibular movement

- **Continuous tooth eruption**
  - As teeth get worn down, the teeth erupt to compensate for the loss in vertical dimension
  - This is why clinically, the height of clinical crowns and the vertical dimension of the face remains constant
  - A stable reference marker is the occlusal surface and the inferior alveolar canal (remains constant)
  - Also, the periodontal-cementum attachment site moves apically
  - Once the central dentin is exposed, wear accelerates and can even reach the pulp

- **Other changes due to attrition**
  - X occlusion: mandibular molars are displaced lingually, and maxillary molars are displaced buccally
  - Mandible repositions increasingly anteriorly, leading to an edge-to-edge incisor relationship and flattening of the canines as well. This allows wide jaw movements
  - Flattening of the temporomandibular joint, which corresponds to the rate of tooth wear

- **Occlusal wear in clinical dentistry**
  - In this modern age, the term “acceptable occlusion” is much more flexible, and can encompass dentitions with multiple flaws
    - It is arguable whether these occlusions would’ve been acceptable in the stone age
    - The clinician should consider patient’s age, lifestyle, and life expectancy of the worn teeth when determining whether the occlusion is acceptable or not
  - There is less tolerance for malocclusion in modern cusped dentitions than in worn ones
    - In the stone age, teeth were quickly flattened so malocclusion wasn’t much of an issue
    - Today, people are keeping their cusps for longer due to change in lifestyle
  - The effects of parafunction (bruxing, clenching) can be minimized in modern days by maximizing vertical tooth loads and minimizing lateral tooth forces during protrusion/laterotrusion/mediotrusion
Module 7 – Jaw forces

Jaw forces

- As mentioned before, cross sectional area of the muscle correlates to its maximum force delivered
  - The masseter is the main contributor
  - High ramal and wide transverse facial dimensions usually have large closing muscle cross sectional areas
- Forces on the jaw: 2D approach
  - Warning: will involve undergrad physics
  - To calculate torque, the force (F) must be multiplied by the lever arm (L)
  - The lever arm refers to a line drawn from the pivot point to the force (F) such that the lever arm and force forms a perpendicular angle
  - Deciphering the diagram on the right
    - This is a 2D diagram calculating the various forces experienced in the orofacial complex when the subject bites down on something with the anterior teeth, much like when using a Lucia Jig
    - Condyle is the pivot point
    - ML = masseter lever arm, MF = masseter force vector
      - ML x MF = creates a torque which is directed in the anti-clockwise direction
    - TL = tooth lever arm, TF = tooth force vector
      - TL x TF = creates a torque which is directed in the clockwise direction
  - When biting, the jaw is in static equilibrium, which means the net force/torque is zero
    - This means that the vertical forces generated by the masseter and teeth have to cancel out
    - ML x MF = TL x TF \( \Rightarrow \frac{MF}{TF} = \frac{ML}{TL} \)
    - As TL increases, TF will decrease
      - Interpretation: the more anteriorly you go (\( \uparrow \) TL), the less force there will be on the teeth. This means the anterior teeth experience much less force than posteriors
    - However, MF has a horizontal component that is not opposed by TF, because TF is purely vertical
      - But as we said before, the total force in the system is zero because the jaw is stationary
      - This means there must be a force somewhere to cancel out the masseter’s horizontal force \( \Rightarrow \) the only place where this can happen is the joint
      - So, the joint experiences a posteriorly oriented force (JF)
      - The downward portion of JF is due to excess force from MF. MF = JF + TF
  - I have no idea what is going on \( \Rightarrow \) posterior teeth experience more force because it is closer to the musculature
- Forces on the jaw: a study
  - Subjects were told to bite with a force gauge placed on 1 tooth at a time
  - As theorized previously, the anteriors do experience less force
    - This is also partly due to the anteriors being occluded only by superficial masseter and medial pterygoid muscles, whereas the posteriors are occluded using all mastication muscles
  - However, the force distribution is not linear. The anteriors (1, 2, 3, 4) basically all receive the same force
  - How can this be? There are 2 explanations
    - Due to the curve of the arch, the anterior teeth are basically all the same distance away from the pivot point (condyle)
    - The anterior teeth are much smaller than the posteriors. This means that all the anteriors are basically situated at the same distance, relative to how spaced out the molars are
Forces on the jaw: 3D approach

- Assume 100N force is the combined force from all the masticatory muscles bringing the mandible upwards

<table>
<thead>
<tr>
<th>Midline incisal clench</th>
<th>Unilateral clench on molar 1</th>
<th>Unilateral clench on molar 3</th>
<th>Non working side interference</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Since the incisors are so far from the contracting muscles, a lot of the force is given the condyles instead -Small amount of force is given to the incisors</td>
<td>-The molar takes much more force as the muscles are so close to it -As a result, force on the working side condyle lessens</td>
<td>-Force on the working side condyle lessens even further, as the molar takes even more load</td>
<td>-Patient attempts to bite on left -Muscles are contracting hard on the left side -Right side interferes -Rotational axis is set up between working side condyle (48N) and site of interference (78N)</td>
</tr>
</tbody>
</table>

- It is safer (for the condyles) to have occlusal loading more on the anteriors than focusing the forces unilaterally on the posterior teeth due to less variances in condylar forces bilaterally

Interproximal forces when biting

- Subjects were told to bite unilaterally on the left side
- Strips were inserted between teeth and force required to pull the strips out of the interproximals were measured
  - Basically how hard a tooth is pushing against its adjacent tooth
- Red bars (20 lb bite force) caused the interproximal forces to increase
- Blue bars (no bite force) meant the interproximals were much looser
- However, the increase in interproximal force does not apply to the whole mouth. It is only present up to the canine on the biting side
- Between arches:
  - At rest: mandibular IP forces are 2x more than maxillary IP forces
  - During clenching: maxillary IP forces exceed the mandibular IP forces

Stresses, strains, and deformations on the mandible

- Assume right sided molar clench (diagram)
- Red = net forces due to muscle contraction
- Blue = force vectors on condyles and teeth due to muscle contraction
- PB = parasagittal bending force of the mandible
- LB = lateral bending at the symphysis (“wishboning”)
- These jaw deformations can be clinically significant in applications like fixed prostheses spanning the mandible’s midline

Methods of measuring occlusal forces

- Fuji Film Corp’s Dental Prescale system: displays contact areas and pressures via colour
- T scan system: records tooth forces on a grid based system
- Both methods involve a thin wafer-type sensor
- Limitations: overestimates posterior tooth forces, doesn’t register contact forces relative to tooth morphology, can give inaccurate readings if bent, and does not detect the direction of the force applied
Module 8 – Articulators

- Will add this section when we become more familiar with articulators and have some clinical time using them

Module 9 – Bruxism

- Etiology
  - Diurnal or nocturnal parafunction affecting up to 20% of the population
  - Awake bruxism: triggered by concentration, stress, or anxiety. Subjects are aware
  - Sleep bruxism: unconscious grinding that affects 8% of the population. Sleep bruxism can be considered a sleep disorder when the following criteria are met:
    - Grinding noises ≥5x per week for the past 3-6 months confirmed by sleeping partner
    - 1 of: non masticatory tooth wear down to dentin with loss of crown height in 1+ sextant OR masseter muscle hypertrophy 2-3x normal size during contraction
    - Positive polygraphic diagnosis with 2+ episodes of nocturnal grinding, 4+ episodes of SB, and 25+ bursts of bruxing muscle activity per hour of sleep

- Typical sleep bruxism episode
  - Light sleep micro-arousals
  - Autonomic events, jaw contractions, and grinding are typical of an episode
  - Opening and closing muscles can co-contract
  - SB appears to be driven by brainstem and limbic pathways
  - In normal subjects, rhythmical masticatory muscle activity (RMMA) can occur about once per hour, but is 2-12 times more frequent in SBs

- Diagnosis
  - Reported by relatives or partners
  - Patient history
  - Signs and symptoms of parafunction (grinding, attrition, cracked teeth, pulpitis, periodontal pain)
  - Comorbidities: jaw muscle pain (post exercise muscle soreness), TMJ crepitus, restricted jaw motion
  - Parafunctional clenching can be more difficult to diagnose, often correlating with muscle hypertrophy and tooth, muscle, and/or joint soreness on waking
  - Note: awake bruxism and sleep bruxism must be differentiated because their managements are different. Clenching and grinding should also be differentiated as the appliances may work differently

- Effects on dentition
  - Attrition, cracked teeth, pulpitis, periodontal pain
  - Eburnation and/or open interproximal spaces (A), dentine wells (B), fractured restorations (C), abfraction (D)

- Management
  - Behavioural approaches like biofeedback, self-monitoring and habit-retraining have short-term effects, but their efficacy has not been established over the long term
  - Some support exists for drug therapy (benzodiazepines, clonidine) but limited to severe and/or recalcitrant SB
  - (Lobbezoo et al 2008) recommends "Triple P" management (Plates, Pep-talk and Pills)
    - This includes hard acrylic occlusal appliances, counselling, and pharmacological intervention
    - The occlusal appliances are used to prevent further dental damage
  - Damaged teeth may require restorative therapy
USING YOUR INTRA-ORAL DENTAL APPLIANCE

This acrylic appliance has been custom made for you, and in conjunction with your other treatment will help improve your temporomandibular disorder. When in your mouth the appliance will prevent tooth wear from activities such as clenching/grinding of your teeth, and, it will evenly distribute jaw forces across your teeth when you bite onto the appliance.

Appliance insertion:
Use finger pressure to align and seat your appliance initially. Once it has been positioned onto the teeth, stabilise it by pushing onto the biting surface of the appliance with your fingers.

Appliance removal:
You will quickly learn the easiest way to remove your appliance from your teeth. Initially try the following: Lift the back of the appliance off your teeth with your fingernails, and then gently wiggle the appliance from your front teeth.

Appliance use:
• Wear your appliance when you go to sleep.
• You may find that you have tooth clenching/grinding habits when you are awake. These habits are often associated with particular activities in which you are deeply concentrating (e.g., driving, reading, etc.). Initially try to consciously stop these habits, however if this does not work, then wear the appliance for short periods during the activities which you associate with the habits.
• Initially, an increase in salivation may occur however this will resolve after a few hours of use.
• Initially, it may be difficult to get to sleep. For the first few days, try increasing your exercise levels so that you are more tired when you go to bed.
• Initially, you may find your speech is altered. As your tongue adapts to the appliance you will find your speech improves.
• Immediately after removing your appliance from your mouth, brush it with water, toothpaste or baking soda to keep it clean.
• Maintain oral hygiene practices (tooth brushing, flossing)

Do not wear the appliance if:
• The appliance seems to increase your pain.
• The appliance causes pressure or pain on the teeth or gums.