Two couple systems

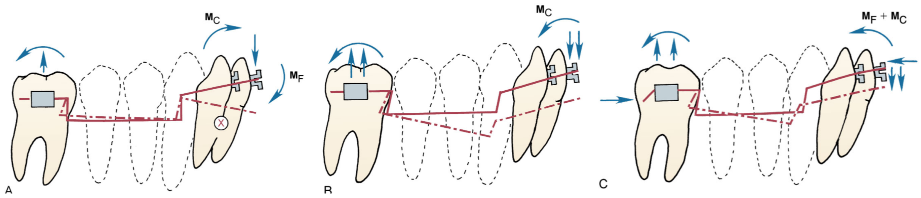
1. Utility arches for intrusion by Ricketts

- = Intrusion arch made from a rectangular wire tied into the incisor brackets.

- ***A:*** *The brackets are anterior of the center of resistance of the incisors:*
  → The moment of the intrusive force tips the crowns facially when it is activated and an additional moment (M_C) in the same direction is created by the couple within the bracket as the inclination of the wire is changed when it is brought to the brackets. The moment of this couple cannot be known, but it is clinically important because it affects the magnitude of the intrusion force.

- ***B:*** *Placing a torque bend in the utility arch creates a moment to bring the crown lingually, controlling the tendency for the teeth to tip facially as they intrude, but it also increases the magnitude of the intrusive force on the incisor segment and the extrusive force and couple on the molars*

- ***C:*** *Cinching back the utility arch creates a force to bring the incisors lingually and a moment of this force opposes the moment of the intrusion force. At the molar, a force to bring the molar mesially is created, along with a moment to tip the molar mesially. Especially if a torque bend still is present, it is difficult to be certain which of the moment will prevail or whether the intrusion force is appropriate. → With this two-couple system, the vertical forces easily can be heavier than desired, changing the balance between intrusion of the incisors and extrusion of the molars.*



- <u>Prevention of facial tipping of the incisors:</u>
  - Apply a force to retract the incisors by cinching or tying back the intrusion arch:
    → Creates a moment in the other direction.
    → Cave:
    - A moment of the force at the incisors opposes the intrusion.
    - A force to bring the molars forward and additionally mesial tip them is created.
  - Place a twist in the anterior segment to torque the incisors lingually.
    (effect can be accentuated by cinching the end of the wire at the molar tube)
    → Intrusive & extrusive force ↑

- *Daviodvitch & Rebellato, 1996:*
  Kraftsystem 3. Ordnung kann die vertikalen Gleichgewichtskräfte neutralisieren oder verstärken.

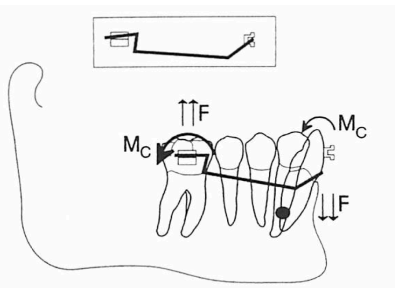


Bild 5: Schematische Darstellung eines Utility-Bogens, der an den Enden nicht umgebogen ist, mit einer V-Biegung für linguale Kronen-/labiale Wurzelrotation des Schneidezahnsegments (labialer Wurzeltorque). Das Kräftepaar zweiter Ordnung an den Molaren und das Paar dritter Ordnung an den Schneidezähnen weisen in die gleiche Richtung, und die an beiden Zähnen wirkenden Gleichgewichtskräfte addieren sich. Die Intrusionskraft an den Schneidezähnen verdoppelt sich, während die Proklination reduziert wird.

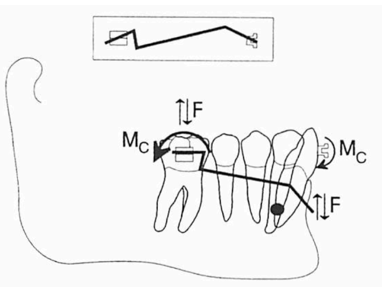


Bild 6: Schematische Darstellung eines an den Enden nicht umgebogenen Utility-Bogens mit einer V-Biegung für labiale Kronen-/linguale Wurzelrotation des Schneidezahnsegments. Das Kräftepaar an den Molaren und das Kräftepaar an den Schneidezähnen sind entgegengesetzt gerichtet. Daher sind auch ihre Gleichgewichtskräfte entgegengesetzt gerichtet, so daß die vertikalen Kräfte an Schneidezähnen und Molaren reduziert werden.

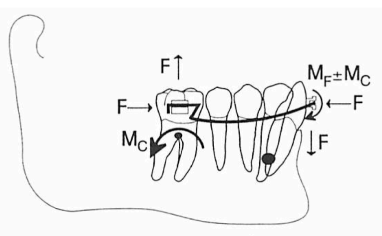
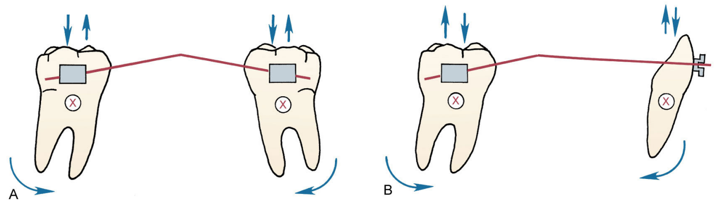
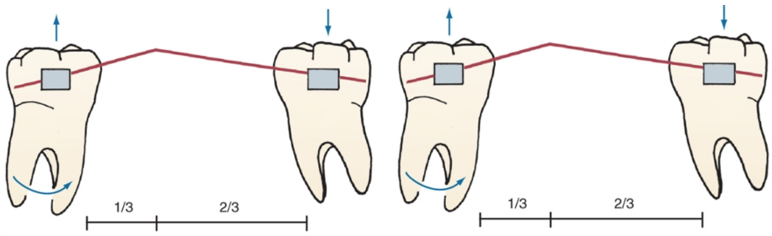


Bild 7: Ein aktivierter Utility-Bogen, eingesetzt in die Brackets der Schneidezähne und Molaren. Der Bogen wurde umgebogen, so daß ein zusätzliches neues Kräftesystem entsteht, das an den Molaren nach mesial und an den Schneidezähnen nach lingual gerichtet ist. Das neue Kräftesystem verläuft weder an den Molaren noch an den Schneidezähnen durch C_{Res}, so daß ein neues M_F an beiden Zähnen erzeugt wird. An Molar und Schneidezähnen wirkt eine Kombination aus dem M_F der Umbiegung und des M_C des aktivierten Utility.

<table>
<tr>
<td>2. Symmetric V-bends

(Burston VI geometry)</td>
<td>
- Equal and opposite couples at the brackets → Equilibrium forces at each bracket are equal and opposite → cancel each other out.
- Not necessarily halfway between two teeth or two groups of teeth, the important quality is, that it creates equivalent couples at both ends.
→ Affected by:
o Bracket width
o Bracket alignment
- If applied between units with unequal resistance (posterior and anterior teeth), the bend must be placed closer to the unit with the greater resistance.
- ø equivalent tooth movements, if the anchorage of one section is much greater than the other.


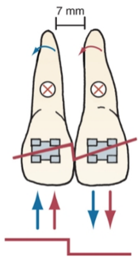
</td>
</tr>
<tr>
<td>3. Asymmetric V-bends</td>
<td>
- Unequal and opposite couples and net equilibrium forces that intrude one unit and extrude the other.
- The absolute magnitude of the involved forces cannot be known, but the relative magnitude of the forces can be determined.
→ Placing the short segment of the wire in the bracket is a good way to visualize the direction of the equilibrium forces.
- The bracket with the larger moment (→ extrusion) has a greater tendency to rotate: → indicates the direction of the equilibrium forces.
- If the bend is moved closer to one of two equal units:
o Moment of the closer unit ↑ (extrusion)
o Moment of the distant unit ↓ (intrusion)
o Equilibrium forces ↑
- $^{1}/_{3}$ of the distance between 2 brackets (point not found in every study): = Geometry IV.
o No moment on the distant bracket, only a single force.
o Point of dissociation.
- If the bend is closer than $^{1}/_{3}$ to one unit: = Burston geometries I/II/III.
o Moments at both brackets in the same direction (instead of opposite).
o Equilibrium forces increase further.
o If the bend is placed to parallel the roots of the adjacent teeth, it will not do so.
- The equilibrium forces increase steadily as the beam moves off-center.


- Define the moments and equilibrium forces clinically:
o Tooth closer to the V-bend = Extrusion
o Tooth closer to the V-bend = Greater moment
o Greater moment = Extrusion
o If a straight archwire is placed over two slots:
The greater angle between the wire and slot indicates the tooth with the greater moment.
→ The greater moment defines the direction of the equilibrium forces.
</td>
</tr>
</table>

Percentage of Total Span to Closest Bracket	Moment Far Tooth/Moment Near Tooth	Force General Condition	DATA FROM EXPERIMENT 16 STEEL, 7-mm SPAN, 0.35-mm BEND	
			Force (gm)	Moment (gm-mm)
Step Bend				
Any	1.0	XX	347	1210/1210
V-Bend				
0.5	−1.0	None	0	803/803
0.4	−0.3	X		
0.33	0	XX		
0.29			353	2210/262
0.2	0.3	XXX		
0.14			937	4840/1720
0.1	0.4	XXXX		

X, XX, XXX, XXXX indicate relative force levels generated at the various V-bend locations.

4. Step bends



- **Creation of two couples in the same direction regardless of location of the bend between the brackets.**
- Parallel step bend = Burston geometry I.
  ø parallel step = Burston geometry II.
- The location has little effect on the magnitude of the moments & equilibrium forces.
- The forces are increased compared to the forces which would be produced by a symmetric V-bend. (because the couples are in the same direction)
- Labor study: Forces from 0.35 mm step bend in a 16 mil SS wire:
  - 347 gm intrusive & extrusive force:
    → Force magnitude is too great for intrusion = extrusion is the result from step bend in a continuous archwires.
  - 1210 gm - mm couples in the same direction.

Forces and couples created by interbracket bends

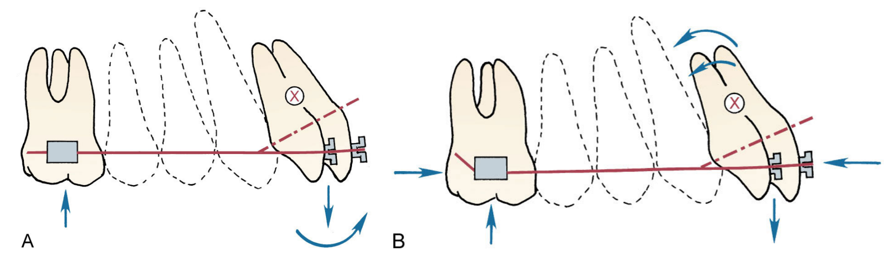
- Interbracket-distance ↑ → F ↓ + M ↓ → = easier to control a 2-couple systems. (distance from the first molar to the lateral incisor needed to obtain the light force necessary for intrusion)
- Interbracket-distance ↑ → position of the V-bend is less critical.

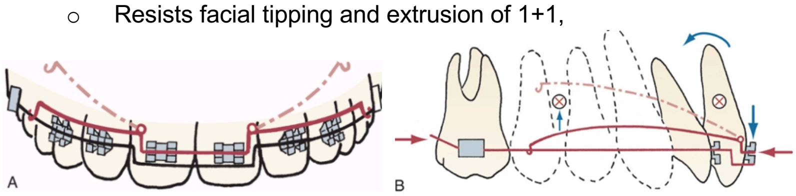
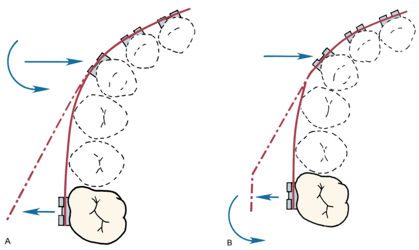
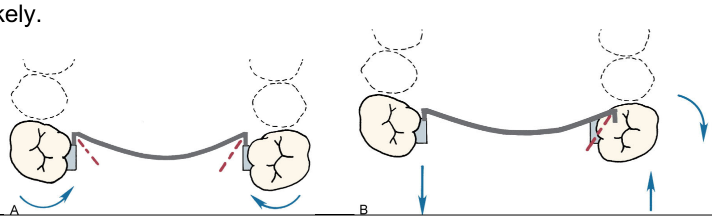
- <u>2 x 4 two-couple wires:</u>
  - 3D effects are produced when the wire goes around the arch from the molars to the incisors.
  - Finite analysis (*Isaacson, 1995*) have shown that the general principles of 2D analysis remain valid when a 3D analysis is done.
  - However, differences exist for long span wires e.g. utility arch:
    - The V-bend at the molar produces a smaller moment and is associated with smaller equilibrium forces than the same V-bend located at the same distance from the incisor segment.
    - If the V-bend moves closer than $^{1}/_{3}$ of the distance to the molar or incisors, the reversal of the moment (that the moment is in the same direction) does not occur.
    - → Effects of utility arches with complex bends are even less predictable.

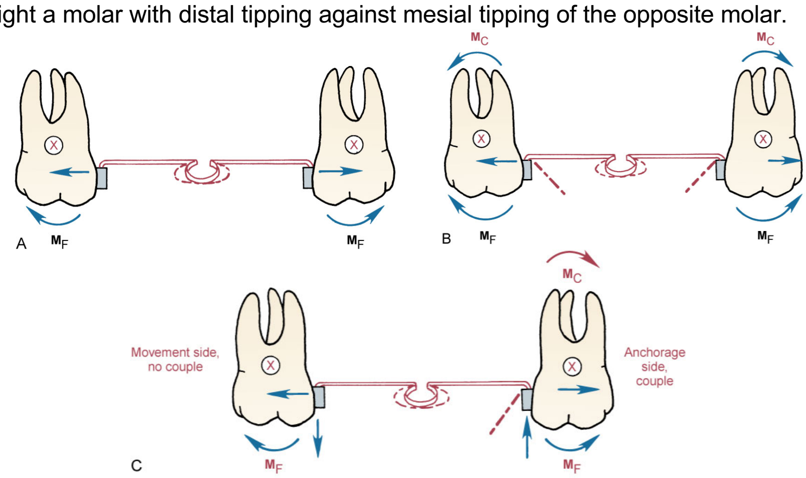
5. Two couple archwires to change incisor inclination

- Archwire free to slide forward through the molar tube:
  - Anterior tipping and extrusion of the incisors. (V-bend closer to the incisors)
  - Indication: Anterior crossbite.

- Archwire cinched behind the molar:
  - Lingual root torque and extrusion for the incisors.
  - Mesial (Row-bow effect) / intrusive / roll facially forces on the molars.



6. One-couple torquing arch by Burston	- Components: • Lateral full dimension stabilizing segments (17x25 ss, 18 slot). • Accessory wire (17x25 TMA, 18 slot) tied into the brackets 1+1 (or 2+2) and activated by bending it down and hooking it between 6+6 and 5+5 to produce the desired moment. • Facultative heavy stabilizing archwire in all the teeth, but the central incisors (and may the lateral incisors): o 17x25 TMA, 18 slot. o Contoured so that it steps below the brackets of 1+1 (21+12) and contacts the facial surface of these teeth. o Cinch back behind the molars. o Resists facial tipping and extrusion of 1+1, 
7. Posterior crossbite corrections: transversal movement of posterior teeth.	- Canines must be incorporated into the anterior anchor segment. (Premolars cannot be tied to the archwire) - <u>Asymmetric expansion or constriction feasible</u>: • Outward bend few mm behind the canine bracket results primarily in expansion of the molar with little rotation ($^1/_3$ position of the 2-couple system) • Outward bend behind the canine + toe-in bend at the molar → Expansion and mesial-out rotation of the molar.  - Large range of activation → teeth can be moved a considerable distance with a single activation (valid for all 2- couple systems). - Cave: Not fail-safe.
8. Lingual arches as two couple systems	- Often employed to prevent tooth movement rather than to create. - <u>Bilateral toe-in bends at the molars:</u> • Equal and opposite couples. • Mesiodistal forces are canceled. • Teeth are rotated to bring the mb cups facially. • A flexible rather than a rigid archwire is needed. • *Ingervall, 1996:* Moments are never symmetric, even if the lingual arch is activated symmetric. → Cold working of the wire changes it's characteristics + influence of the occlusion. - <u>Unilateral toe-in bend:</u> • Rotates the molar on the side of the bend. • Creates a force to move the other molar distally. (Systemdrehung in Gegenrichtung) • Mesial movement of the molar on the side of the bend is limited from the contact with other teeth. (sign. distal movement of both teeth is unlikely) • Net distalization of both molars by bends of this type on first one side, then the other, have been claimed. Sign. distal movement of both teeth is however not likely. 

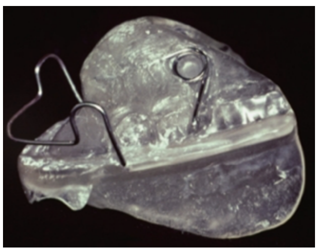
	- <u>Bilateral expansion of molars by opening a loop in the middle:</u>
	  • Moment of expansion tips the crowns facially.
	
	- <u>Symmetrical torque application while the molars are expanded:</u>
	  • Provides bodily movement rather than tipping.
	
	- <u>Unilateral crossbite:</u>
	  • Buccal root torque (lingual crown torque) on one side pitted against buccal tipping on the other side.
	  • = Twist in the wire on one side creates stationary anchorage to tip the opposite molar facially.
	  • Particularly effective if the wire is rounded on the movement side.
	  = Conversion to a one couple device.
	  • *Ingervall, 1995:* Asymmetric expansion with tipping against torque.
	    ○ Risk to develop a crossbite on the torque site.
	    ○ Extrusion at the site with more expansion.
	    ○ Intrusion at the side with less expansion (torque side).
	
	- <u>2nd order correction:</u>
	Upright a molar with distal tipping against mesial tipping of the opposite molar.
	
	
	Note:
	- Buccal root torque:
	  • Intrusion
	  • Mesial tipping (root distal, crown mesial)
	- Palatal root torque:
	  • Extrusion
	  • Distal tipping (root mesial, crown distal)

Segmented arch mechanics	- Using one- / two-couple systems: → Engineering analysis can provide an approximation of the forces and moments engaged.
	- Lingual arches (0.036'' / 0.032'' x 0.032'' ss).
	- Stabilizing wire segments in the brackets of anchor teeth (21x25 ss) for stabilization.
	- Sliding of archwires through brackets is avoided, because the resistance to sliding introduces uncertainties in the calculation of forces and moments.
	(Sliding is applied only for the final stages).
	
	- Pro:
	  • Tooth movements become possible which are impossible with continuous arches. (unless TADs are used)
	
	- Contra:
	  • Greater complexity of the appliance, danger to overlook something.
	  • Chairtime ↑
	  • Not fail-safe: No control mechanism for the distance over which a tooth can be displaced if something goes wrong.
	
	- Skeletal anchorage replaces nowadays the need for segmented mechanics.

Continuous arch mechanics	- = Extremely complex multi-couple force system. - An initial small movement of one tooth changes the whole system. - Forces and moments are not well defined. - Excellent fail-safe properties. - Chairtime ↓

Chapter 10:

Contemporary Orthodontic Appliances

Removable appliances	
Pros and contras	- Cons: ○ Compliance depending. ○ Difficult to obtain a two point contact on the teeth: → Complex tooth movements are difficult to achieve. - Pros: ○ Fabricated in the laboratory → reduced chair time. ○ Removal on socially sensitive events, almost invisible. ○ Some type of growth guidance tx possible that cannot be carried out readily with fixed appliances.
History and development	- America: • Tx was used to be based on fixed appliances. (Angel's doctrine to place every tooth precisely) • Introduction of removable appliances only 1960/70 after an American study that showed that significant skeletal changes can be achieved with removable appliances. - Europe: • Precious metal was less available. (precious metal in dentistry was banded by the Nazis) • Social welfare system that placed the emphasis on limited tx, but for a large number of people. - **1900**: Monobloc by **Robin** - **Early 1900s**: **George Croza** (US) ○ Removable appliance fabricated entirely of precious metal. ○ Clasps for the molars. ○ Heavy gold wire as frame work. ○ Lighter gold fingersprings.   - **1908**: Activator by **Andresen**: (without knowing the monobloc by Robin) ○ Angulated flutes in the acrylic to guide eruption of the teeth. ○ Displacement spring in the palate: → patient must bite into the activator to keep it in place. ○ Loosely fitting: → Was thought to activate the musculature, but nowadays not supported by research → clasps preferred. ○ 1925: Andresen become professor in Oslo and gains a lot of clinical expertise with the activator. 

- **Häuptl** (Germany)**:**
  Recognizes that the only stable tooth movement was produced by natural forces and that alteration in function by the new appliances would give stable correction of malocclusion.
  (total contrary to Angles belief in the US!)
  1936: Publication of the book “Funktionskieferorthopädie” with Andresen.

- **Martin Schwarz**:
  - Split plate with jackscrew to expand arches.
  - Arrowhead clasp.

- **Philip Adams**: Adams crib.

- **1970**: Animal experience showing that skeletal changes really could be produced by posturing the mandible to a new position + hypothesis that true stimulation of mandibular growth could be achieved.

Functional appliances for growth modification

- Functional appliance:
  Change of the posture on the mandible → pressure created by the stretch of the muscles and soft tissues are transmitted to the dental / skeletal structures → movement of teeth or modification of growth.
  = Depends only on soft tissue stretch and muscular activity to produce the desired effects.

TABLE 10.1 Functional Appliance Components

Component	Comment
Functional Components	
Lingual flanges	Contact with mucosa; most effective
Lingual pad	Contact with mucosa; less effective
Sliding pin and tube	Contact with teeth; variable tooth displacement
Tooth-supported ramps	Contact with teeth; tooth displacement likely
Lip pads	Secondary effect only on mandibular position
Tooth-Controlling Components	
Arch Expansion	
Buccal shields	Passive, effective
Buccinator bow, other wire shield	Passive, less effective
Expansion screws and/or springs	Must activate slowly; questionable stability
Vertical Control	
Occlusal or incisal stops	Prevent eruption in discrete area
Bite blocks	Prevent eruption of all posterior teeth
Lingual shield	Facilitate eruption
Stabilizing Components	
Clasps	No effect on growth modification
Labial bow	Keep away from incisors, lingual tipping undesirable
Anterior torquing springs	Needed to control lingual tipping, especially with headgear-activator combination

- Construction bite:
  - Cl.II: Mn is advanced.
  - Cl.III: Mn is rotated downward.

- 4 Categories:
  1. Passive tooth-borne:
     - No intrinsic force-generating capacity from springs or screws.
     - Depends only on soft tissue stretch and muscular activity to produce the desired effects.
     - Examples: Bionator, Herbst appliance, bonded twin block

     - **Carrier motion appliance:**
       - Pro: Minimal lateral restriction of the mn movement.
       - In theory forces are similar to a Herbst appliance, but good studies are not available.

     - **Forsus:**
       Compared to Herbst appliance:
       - Skeletal effect on mx growth ↑
       - Forward movement of the mn dentition ↑
       - Skeletal mn advancement ↓

  2. Active tooth-borne:
     - Expansion screw or springs to move teeth.
     - Produce tooth movement that often replaces jaw growth / modification with camouflage tooth movement.
     - Used much less than previously.
     - Examples: Modified activator / bionator

  3. Tissue- borne:
     - Contact of the appliance with the teeth is avoided.
     - Hold the lips and cheeks away from the dentition.

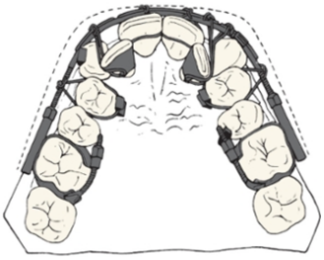
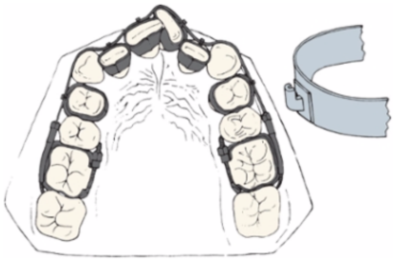
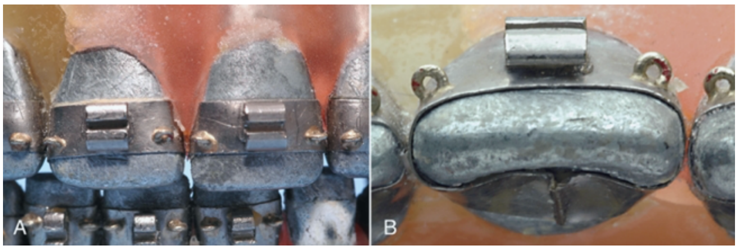
     - **Frankl appliance:** (1969)
       - Large buccal shields and lips pads reduce cheek and lip pressure on the dentition and provide the expansion of the maxillary arch.
       - Lingual pads dictate the mn position.
       - Effective but needs a long tx time (+/- 5 y).
       - Available for cl.II, cl.III and open bite.
       - Most parts of the appliance are restricted to the buccal vestibule:
         → Speech is easier and 24h wear easier.

	4. <u>Hybrid:</u> o Components that are common to functional appliances but are combined to meet for specific needs. o Often used for tx of jaws asymmetry. o Used primary in late preadolescent children and during adolescent growth spurt.
Important factors for removable appliances	- Compliance: If it is not high at the beginning it will decrease (known from studies). → Change tx plan for noncompliant patients. - Right timing.
Removable appliances for tooth movement in children	
Active plate for arch expansion	- Activation of the screw produces a heavy force which decays rapidly. - If the screw is activated too rapidly → appliance is displaced from the teeth rather than the arch is expanded.
Removable appliances with springs for tooth movement	- Nearly optimum light continuous forces can be produced by the springs. - Only one-point contact with the tooth → other movements than tipping difficult.

Clear aligner therapy	
Development	- 1980s: Introduction of vacuum formed aligners. - Initially used for retention proposes. - Late 1990s: Computerization of the process of producing a sequence of casts with incremental changes on which aligners could be fabricated.

Indication	- Only small amount of tooth movement possible with one aligner:
	(elastic range = ~ 0.2 mm, maximum stress of plastic = ~ 1 mm)
	→ reshape the aligner, make a new one.
	- Satisfactory for simpler cases, extra instructions by the doctor needed for complex tx.
	- Accuracy ratio achieved to predicted changes: ***18-47%*** depending on the tooth movement.
	- Bleaching is possible with aligners. Better after tx, because teeth are already sensitive during tx. Tooth movement and bleaching create a transient pulpitis.
	- Bite ramps on the incisors to disclude posterior teeth can prevent transient posterior intrusion as arches are leveled.
	- Bite blocks between posterior teeth can help to close an anterior open bite by intrusion. Cave: Historically bite blocks have not been effective in doing this and much of the bite closure is likely to be incisor elongation.
	
	Clear Aligner Therapy (CAT) Applicability
	
	CAT Performs Well
	• Mild-to-moderate crowding
	  • With arch expansion
	  • With interproximal reduction (IPR)
	• Posterior dental expansion
	• Close mild-to-moderate spacing
	• Intrusion of incisors (one or two tooth segments)
	• Lower incisor extraction for severe crowding
	• Tip molar distally
	
	Requires Bonded Attachments
	• Extrusion of incisors
	• Incisor or canine rotation correction
	• Translation of molars
	
	Requires Attachments and Modified Aligners
	• Premolar extraction space closure
	• Molar relationship correction
	• Deep bite correction
	• Open bite correction (?)
	
	CAT Does Not Perform Well
	• Prolonged treatment in children
	• High canines
	• Severe rotations (especially rounded teeth)
	
	- Possible causes if teeth do not track the tx plan:
	  ○ Insufficient wear of the aligners
	  ○ Insufficient IPR
	  ○ Insufficient crown height or shape to allow a grip on the tooth to be moved
	  ○ Wrong type or position of bonded attachments
	  ○ Movement created in the clean check that is too fast to be biologically possible.

Invisalign production	1. IO scan or impression, bite registration. 2. Digitalization. 3. Tx stages following the doctor's instructions. Cave: Sequence of steps and the amount of movement between steps is specified by algorithms in the software: → The preliminary plan is placed online for clean check. 4. Fabrication of stereolithographic models and formation of a plastic retainer over each model. 5. IPR / bonded attachments → Extension of possible tooth movements. 6. Verify that the tooth movements are tracking with the series of aligners during tx (enough worn / IPR, correct bonded shapes, enough grid on the teeth). - Midcourse correction refinement if necessary.

Fixed appliances	
Edgewise appliance	- Rectangular archwire in a rectangular slot. - All contemporary appliances today except Begg appliance (=ribbonwise).
History	- <u>Angle's progression to the edgewise appliance</u> **1. E-Arch late 1800's:** • Bands around molars + heavy labial archwire. • Teeth tied to the arch for expansion → only tipping. • Mechanism to advance the arch and increase the perimeter.  **2. Pin and Tube:** • Bands on other teeth with a vertical tube on each band into which a soldered pin from a smaller archwire was placed. • Great precision possible, impractical for use. **3. Ribbon Arch:** • Vertically positioned rectangular slot behind the tube. • Ribbon archwire 10x20 gold placed into the vertical slot and hold with pins. • Good spring qualities. • Relatively poor control of root position (too much resiliency of the archwire)  **4. Edgewise** • Slot orientated horizontal, 22x28 mils. • Precious metal wire 22x28 mil used after extensive experimentation: → excellent control of crown and root position in all 3 planes of space. • Rectangular wire 90° rotated compared to the ribbon arch → wider than small → could be twisted to create torque. • Eyelet at the corner of the bands with the brackets.  - <u>Labiolingual appliance:</u> (Disappeared nowadays) • Bands on the molars. • Heavy labial and lingual archwire. • Fingersprings soldered to the archwires to move individual teeth. - <u>Twin wire appliance</u>**:** (Disappeared nowadays) • Bands on the molars and incisors.