Mechanical Principles in Orthodontic Force Control

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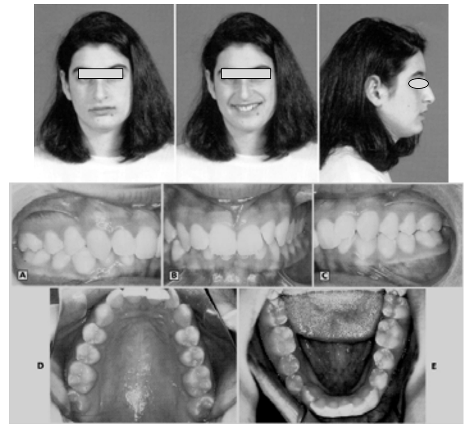

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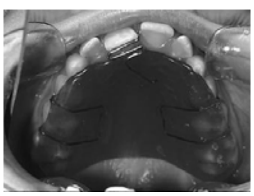
Two Types of Orthodontic Appliances: Removable vs. Fixed



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Fixed appliances

- Bands
- Brackets
- Wires
- Accessory appliances

Brackets

- Metal bracket

- 24K plating gold bracket

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Brackets

- Clear Bracket

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Plastic brackets

- Staining and discoloration
- Poor dimensional stability
- Larger friction

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Ceramic brackets


- Advantages over plastic brackets:
  - – Durable, resist staining
  - – Can be custom-molded
  - – Dimensionally stable
- Disadvantages over metal brackets:
  - – Bulkier than metal bracket
  - – Fractures of brackets
  - – Friction is bigger than that in metal bracket
  - – Wear on teeth contacting a bracket
  - – Enamel damage on debonding

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- Metal-reinforced ceramic bracket

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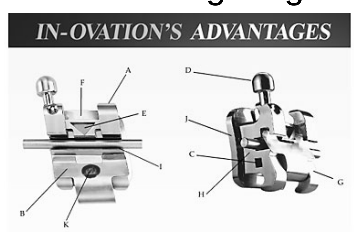
Self ligating bracket

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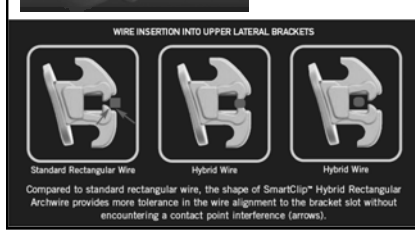
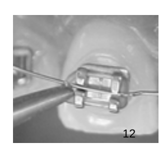
Self ligating bracket

"Smart" Clips





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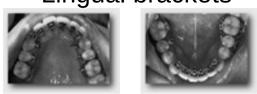
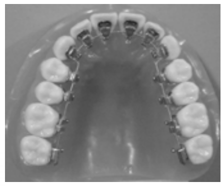
Invisible orthodontics?

- Lingual brackets





- Invisalign

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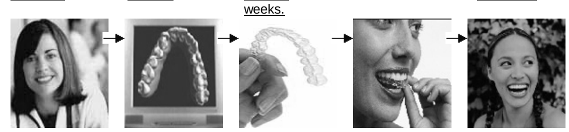
Step 1: Visit your orthodontist or dentist

Step 2: Invisalign® makes your aligners

Step 3: You receive your aligners in a few weeks.

Step 4: You wear your aligners.

Step 5: You've finished treatment!



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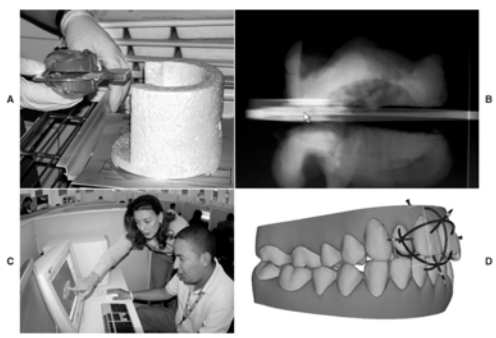
Invisalign



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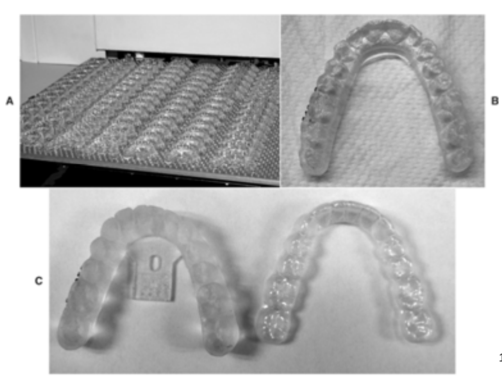

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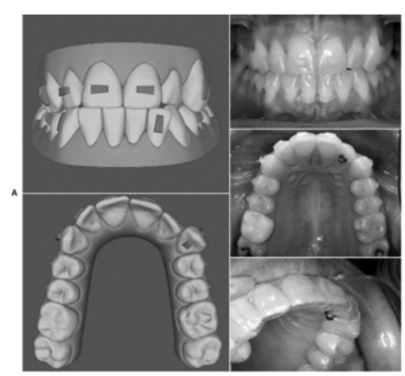

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Clear aligner therapy (CAT) applicability

CAT performs well:

- Mild-moderate crowding with IPR or expansion
- Posterior dental expansion
- Close mild-moderate spacing
- Absolute intrusion (1 or 2 teeth only)
- Lower incisor extraction for severe crowding
- Tip molar distally

CAT does not perform well:

•Dental expansion for blocked-out teeth
•Extrusion of incisors*
•High canines
•Severe rotations (particularly of round teeth)
•Leveling by relative intrusion
•Molar uprighting (any teeth with large undercuts)
•Translation of molars*
•Closure of premolar extraction spaces*

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Fig 11-16

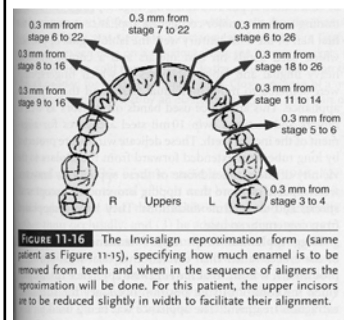

FIGURE 11-16 The Invisalign reproximation form (same patient as Figure 11-15), specifying how much enamel is to be removed from teeth and when in the sequence of aligners the reproximation will be done. For this patient, the upper incisors are to be reduced slightly in width to facilitate their alignment.

0.1-0.5 mm in thickness

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Invisalign vs. braces

- patients treated with Invisalign relapsed more than those treated with conventional fixed appliances.
  - Kuncio D, et al. Angle Orthod 2007;77: 864-9

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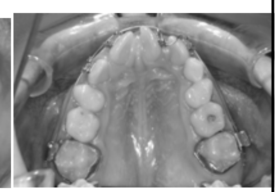

6 weeks later

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Wires

- Type:
  - NiTi wire (Nickel-Titanium wire)
  - TMA wires (Titanium-Molybdenum-Alloy)
  - Stainless steel wire
- Shape
  - Round wire
  - Rectangular wire

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Wire

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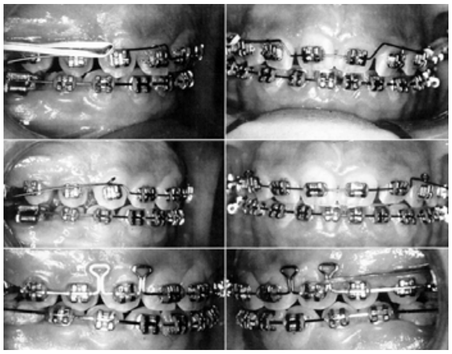
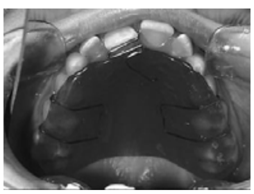
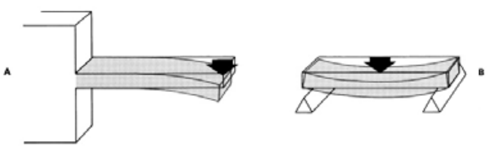
Fixed appliance: properties of arch wires
– related to force levels, rigidity, formability, etc.



General Characteristics of Orthodontic Forces

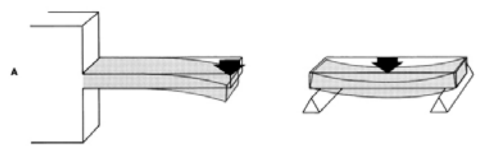
- Optimal: light, continuous
  - Ideal material
    - Maintains elasticity
    - Maintains force over a range of tooth movement



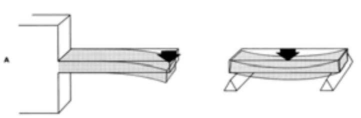


Materials & Production of Orthodontic Force

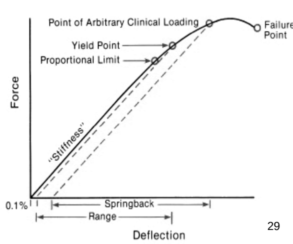
- Elastic behavior
  - Defined by stress-strain response to external load
    - Stress= internal distribution of the load; force/unit area
    - Strain= internal distortion produced by the load; deflection/unit length



Orthodontic Model: Beam

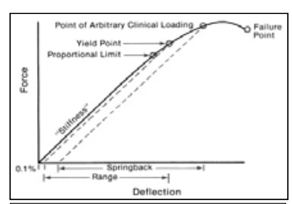


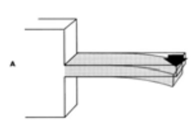
- Force applied to a beam = stress
- Measure deflection = strain; examples:
  - Bending
  - Twisting
  - Change in length

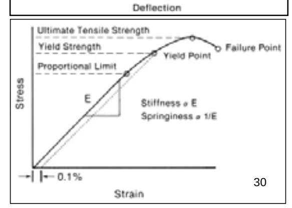


Beam Properties in Orthodontics

- Defined in force deflection or stress-strain diagrams
- Useful properties:
  - Stiffness
  - Range, springback
  - Strength



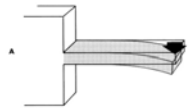


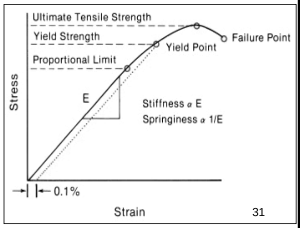


Bending Properties of an Orthodontic Wire

Defined by 3 points

1. Proportional limit
   - Point at which permanent deformation is first observed
   - Similar to "elastic limit"
2. Yield strength
   - Point at which 0.1% deformation occurs
3. Ultimate tensile (yield) strength
   - Maximum load wire can sustain

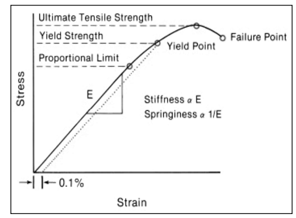




Stiffness of an Orthodontic Wire

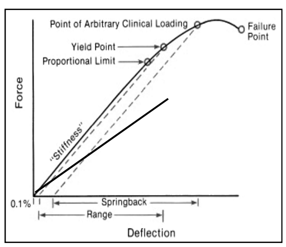
Modulus of elasticity (E)

- Young's modulus
- Stiffness below proportional limit
- Slope of load-deflection curve
- Stiffness α E
- Springiness α 1/E



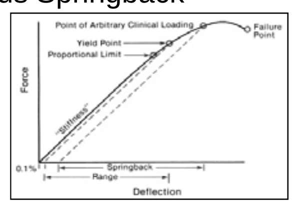
Stiffness versus Springiness

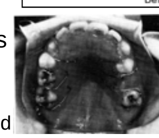
- Reciprocal relationship
  - Springiness= 1/stiffness
- Related to elastic portion of force-deflection curve (slope)
  - More horizontal= greater springiness
  - More vertical= stiffer

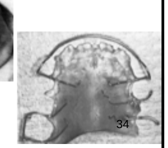


Range versus Springback

- Range
  - Distance wire will bend elastically before permanent deformation
- Springback
  - Found after wire deflected beyond its yield point
  - Clinically useful
    - Wires often deflected past yield point

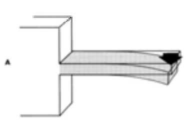


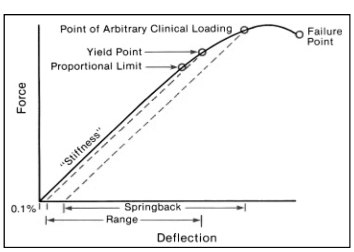




Relationship of Strength, Stiffness & Range

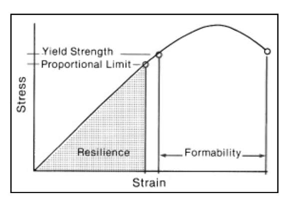
- Strength = stiffness x range





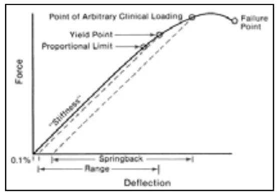
Resilience, Formability

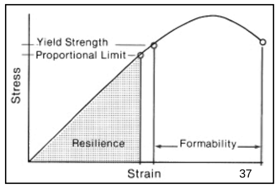
- Resilience
  - Area under stress-strain curve to proportional limit
  - Represents energy storage capacity
- Formability
  - The amount of permanent deformation a wire can withstand before breaking



Ideal Orthodontic Wire Material

- Deflection properties:
  – High strength
  – Low stiffness (usually)
  – High range
  – High formability
- Other properties:
  – Weldable, solderable
  – Reasonable cost
- No one wire meets all criteria!
  – Select for purpose required





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Wire Materials

- Precious metal alloys
  – Before 1950's: gold alloys, corrosion resistant
- Stainless steel, cobalt-chromium (elgiloy®) alloys
  – Improved strength, springiness
  – Corrosion resistant: chromium
    - Typical: 18% chromium, 8% nickel
- Nickel-titanium (NiTi) alloys
  – 1970's applied to orthodontics
  – Demonstrates exceptional springiness
    - Two special properties: shape memory, superelasticity

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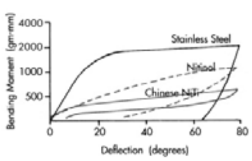
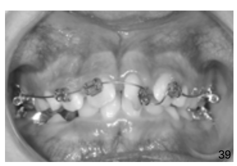
Austenitic NiTi (A-NiTi)

- Introduced 1980's
  – Demonstrate superelasticity
    - Large reversible strains
      – Over wide range of deflection, force nearly constant
      – Very desirable characteristic
    - Non-elastic stress-strain (force deflection) curve
    - E.g., Chinese Ni-Ti





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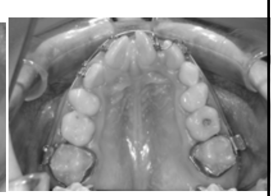
Uses of Ni-Ti Arch wires

- Good choice:
  – Initial stages of Tx
  – Leveling and aligning (good stiffness, range)
- Poor choice:
  – Finishing (poor formability)



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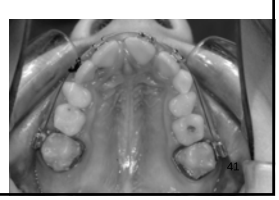

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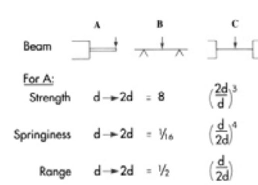
Elastic Properties: Effects of Size and Shape

- Wire properties
  – Significantly affected by wire (beam) cross section and length
    - Magnitude of change varies with wire material
    - Similar proportional changes among wire materials



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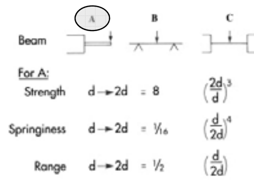
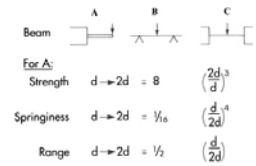
Elastic Properties: Effects of Size and Shape Effects of Diameter: Cantilever

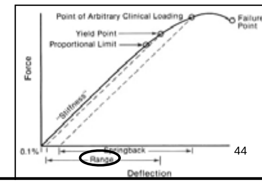
- Strength
  - Changes to third power
    - Ratio between larger to smaller beam
    - E.g., double diameter: deliver 8x strength
- Springiness
  - Changes to fourth power
    - Ratio between smaller to larger beam
    - E.g., double diameter: wire 1/16 as springy



Effects of Diameter: Cantilever

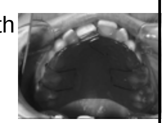
- Range
  - E.g., double diameter: half the range

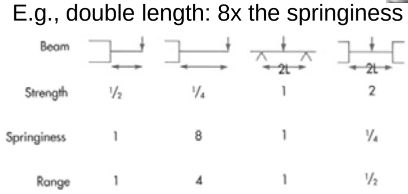




Effects of Length (Cantilever)

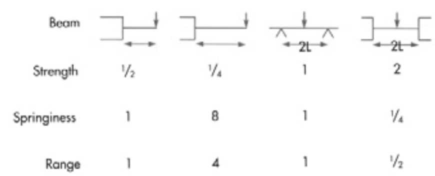
- Strength
  - Decreases proportionately
  - E.g., double length: half the strength
- Springiness
  - Increase by cube of ratio
  - E.g., double length: 8x the springiness





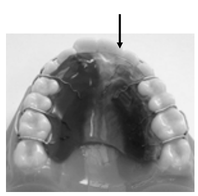
Effects of Length (Cantilever)

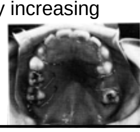
- Range
  - Increases by square of ratio
  - E.g., double length: 4x the range

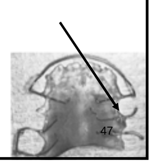


Spring Design

- Requires appropriate balance:
  - Heavy wire:
    - High strength, high force, low range
  - Light wire:
    - Low strength, low force, high range
- Example: removable appliance
  - Finger spring
  - High strength needed to avoid deformation
  - Force can be reduced by increasing wire length
    - Add helix

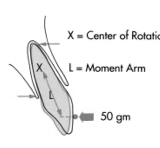






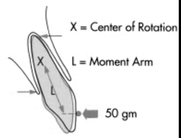
Biomechanical <u>Design Factors</u> in Orthodontic Appliances

- Terms:
  - <u>Force</u> (F): load applied to object that will tend to move it to a different position in space
    - Units: grams, ounces
  - <u>Center of resistance</u> (C_R): point at which resistance to movement can be concentrated
    - Object in free space: C_R=center of mass
    - Tooth root: C_R=halfway between root apex and crest of alveolar bone



Design Factors in Orthodontic Appliances

– Moment: product of force times the perpendicular distance from the point of force application to the center of resistance
  - Units: gm-mm
  - Created when line of action of a force does not pass through the center of resistance
    – Force will translate and tend to rotate object around center of resistance



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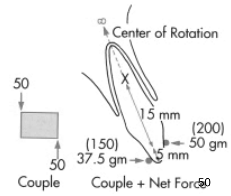
Design Factors in Orthodontic Appliances

– Couple: two forces equal in magnitude but opposite in direction
  - No translation
  - Produces pure rotation around center of resistance



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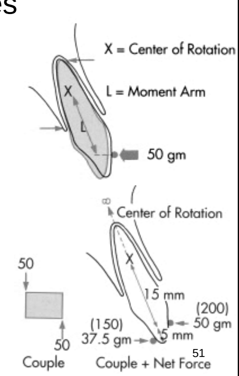
Design Factors in Orthodontic Appliances

– Center of rotation: point around which rotation occurs when object is being moved
  - Can be controlled with couple and force
  - Can be used to create bodily tooth movement



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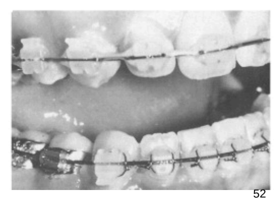
Friction

- Can dramatically affect the rate of tooth movement
- Considerations:
  1. Contact angle between orthodontic bracket and arch wire
  2. Arch wire material
  3. Bracket material



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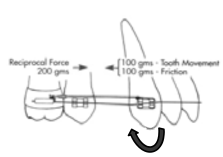
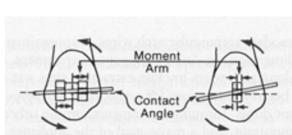
Contact Angle

- When sliding a tooth on an archwire:
  – Tooth tips
  – Further tipping prevented by moment created as bracket contacts wire = contact angle
  – Increase contact angle = increase resistance
    - Greater force needed to overcome friction





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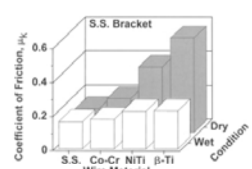
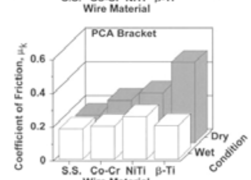
Friction and Tooth Movement

- Effects of arch wire material
  - The greater titanium content, the more friction
    – Due to surface reactivity (chemistry)
  - Sliding resistance: titanium > stainless steel arch wires





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Tooth Movement

- Effects of bracket material
  - Stainless steel: least friction
  - Titanium brackets: high friction likely
  - Ceramic:
    - Rough, hard surface
    - Increases friction
  - Ceramic with steel slot
    - Reduced friction

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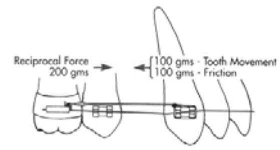
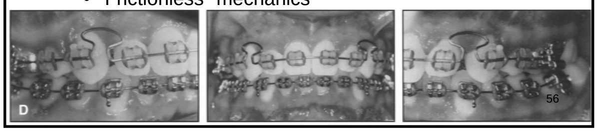
Alternatives to Sliding (Friction)

Segmented mechanics or closing loops mechanics

- Activate loops
- Loops close to original shape
- Retract teeth toward space as loops close
- No sliding, no friction
- “Frictionless” mechanics





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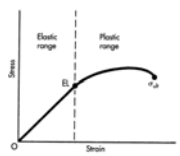
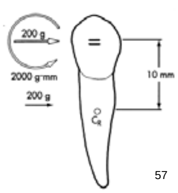
Summary

- Ideal orthodontic forces
- Wire properties
  - Strength, stiffness, range (springback)
  - Resilience, formability
- Wire materials
- Changes in diameter, length
- Design factors
  - Force, center of resistance, moments, couples, center of rotation
  - Use of rectangular wires: couples
- Friction
  - Contact angle, wires, brackets





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