Biomechanics in Orthodontics

Science of Mechanic + Biological System

MODERN SMILE INSTITUTE

BIOMECHANICS

MECHANICS—IS THE DISCIPLINE THAT DESCRIBES THE EFFECT OF FORCES ON BODIES.

BIOMECHANICS—STUDY OF MECHANICS AS IT AFFECTS THE BIOLOGIC SYSTEMS.

BIOMECHANICS— APPLICATION OF MECHANICS TO THE BIOLOGY OF TOOTH MOVEMENT.

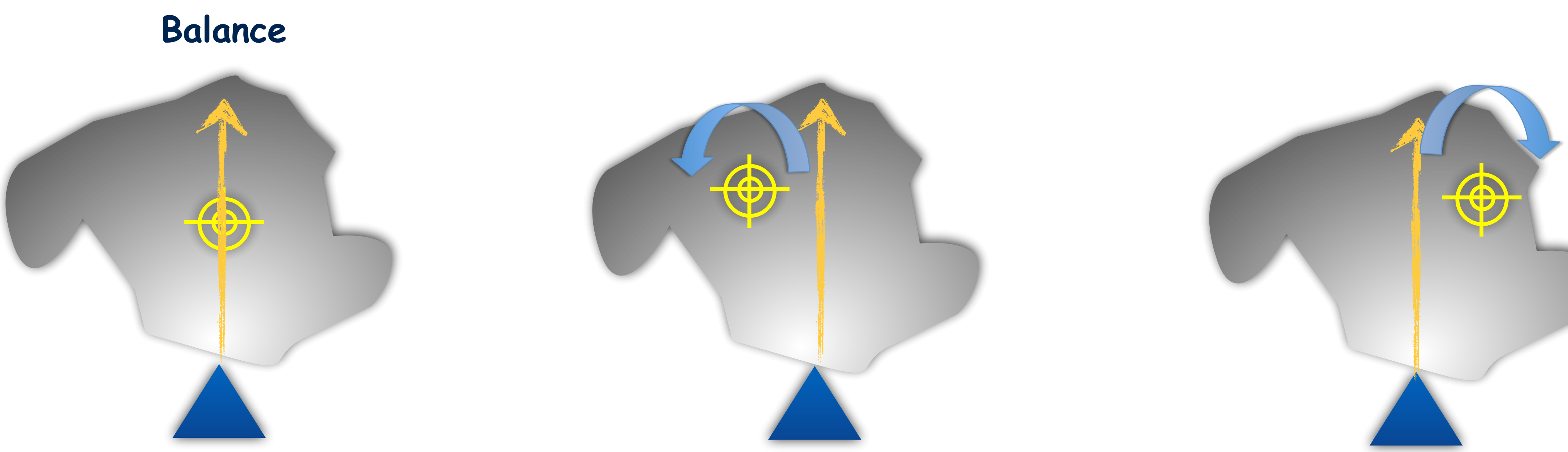
The Basic Principle of Physical science

MECHANIC

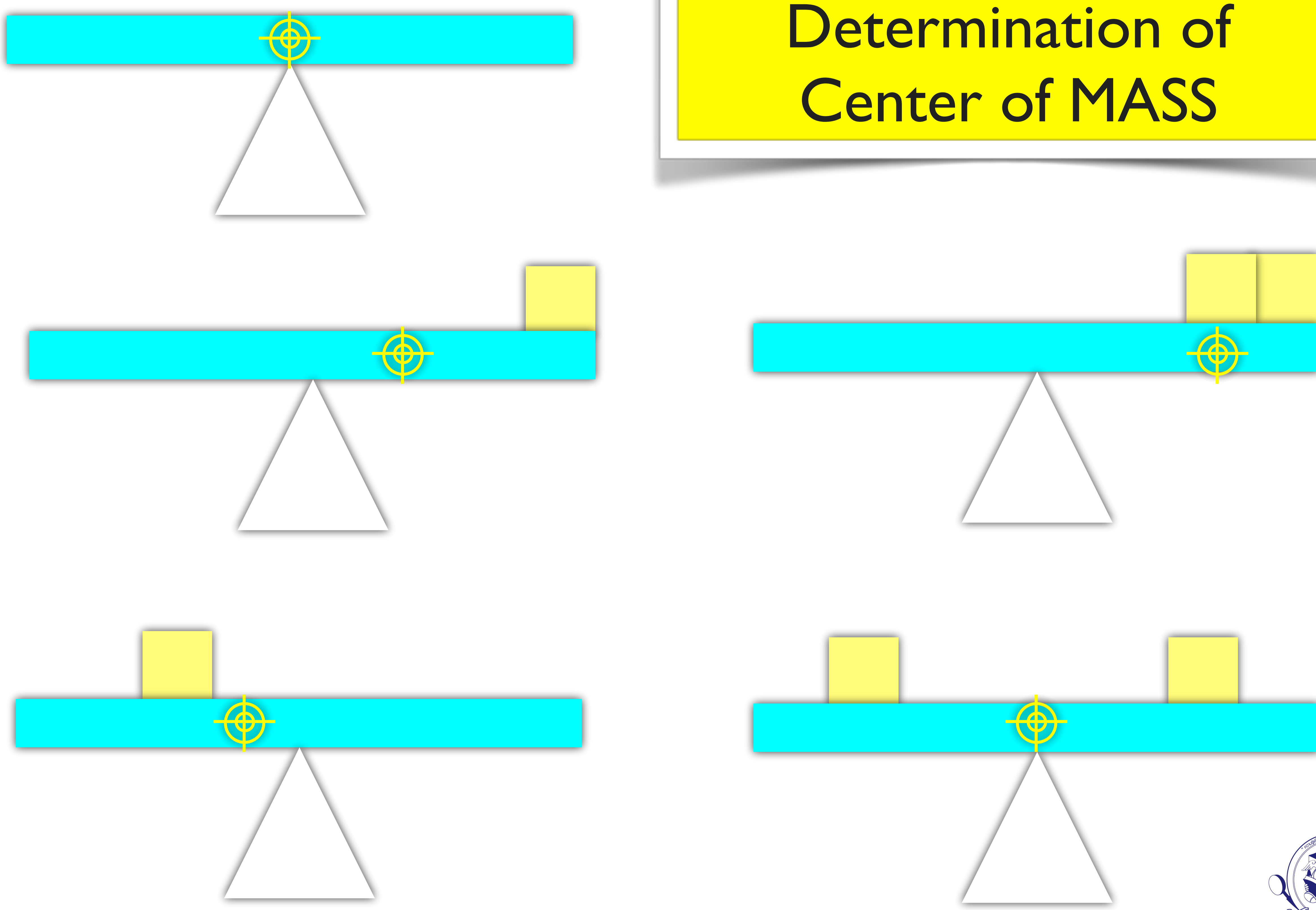
Rule of Mass

- Center of Mass (Free body) exists in all free object
- Center of Gravity (Free body)
- Center of Resistance (Restrained body)

The point that the force applied pass through any object to move linearly without any rotation or tilted

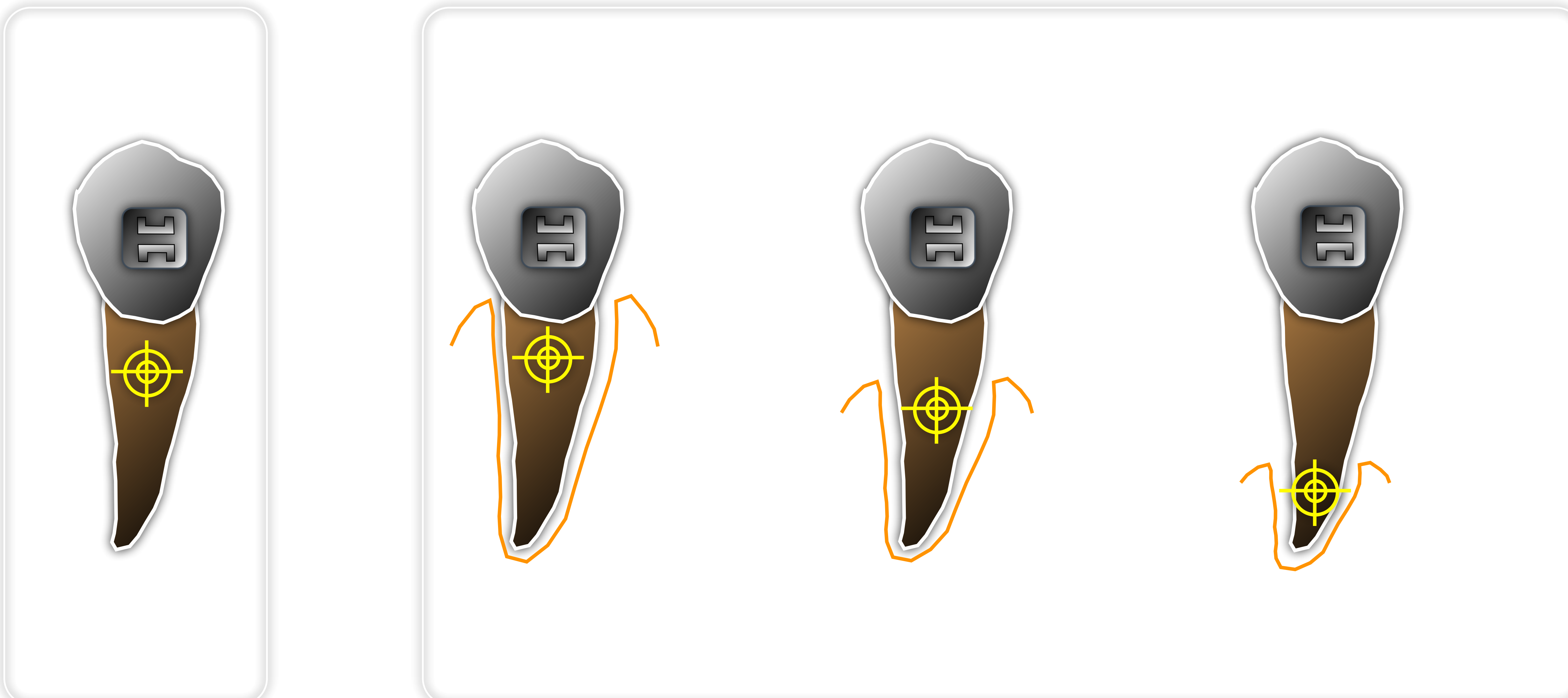


Determination of Center of MASS

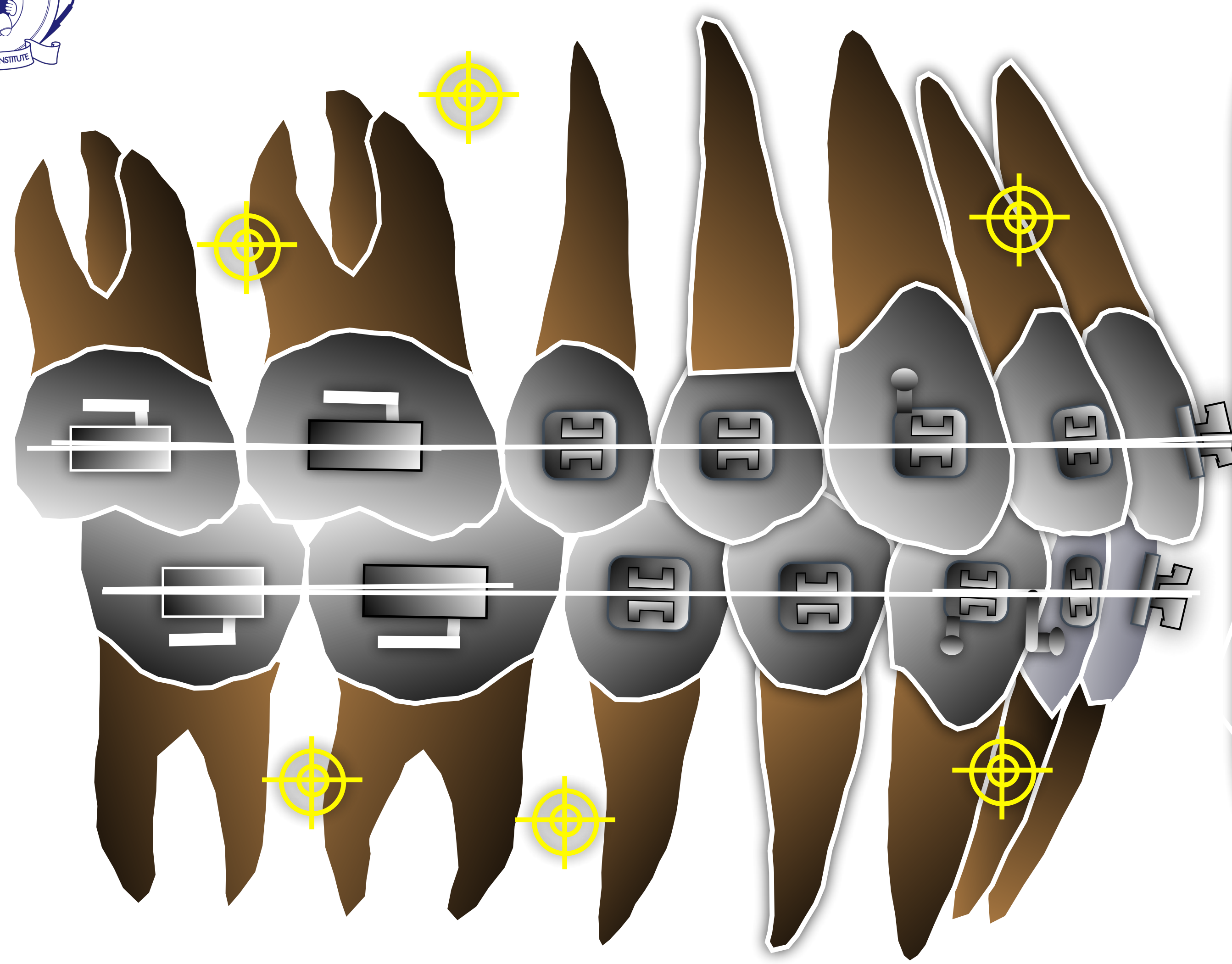


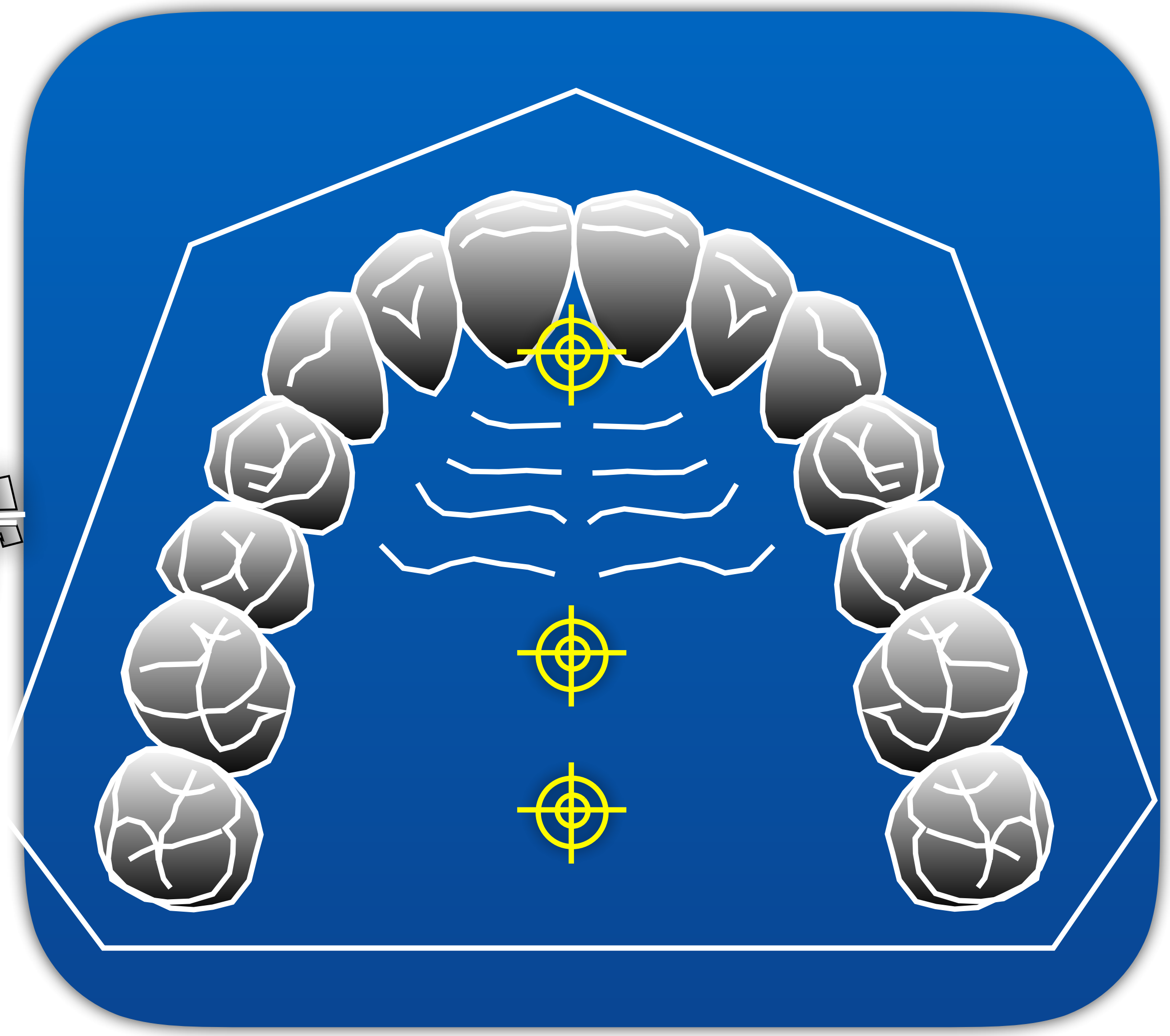
Determination of Center of Resistance

- Center of Mass (Free body) will never change
- Center of Resistance (Restrained body) can be changed according to the environment and not coincide with the CM

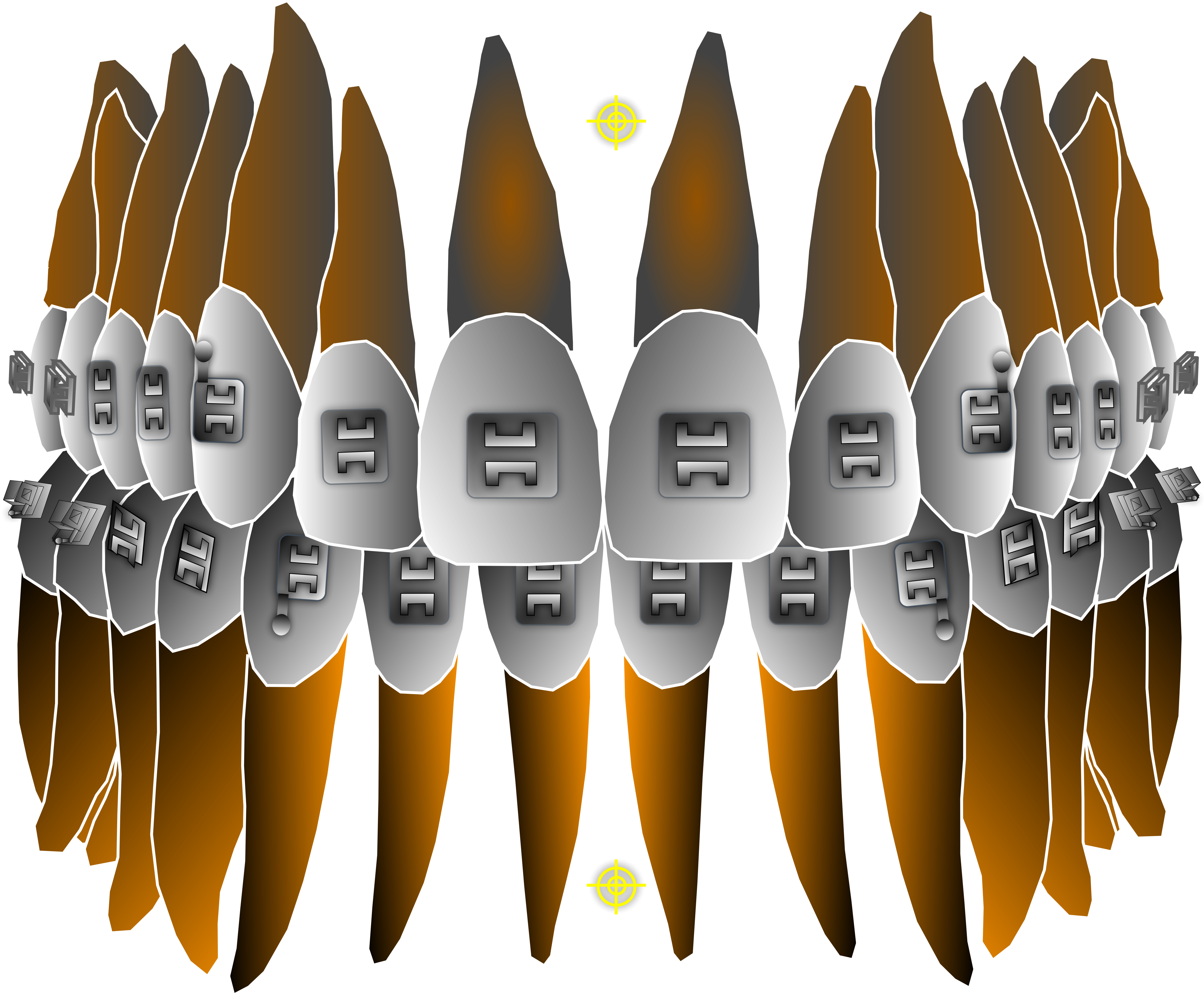


Location of Center of Resistance in Orthodontics





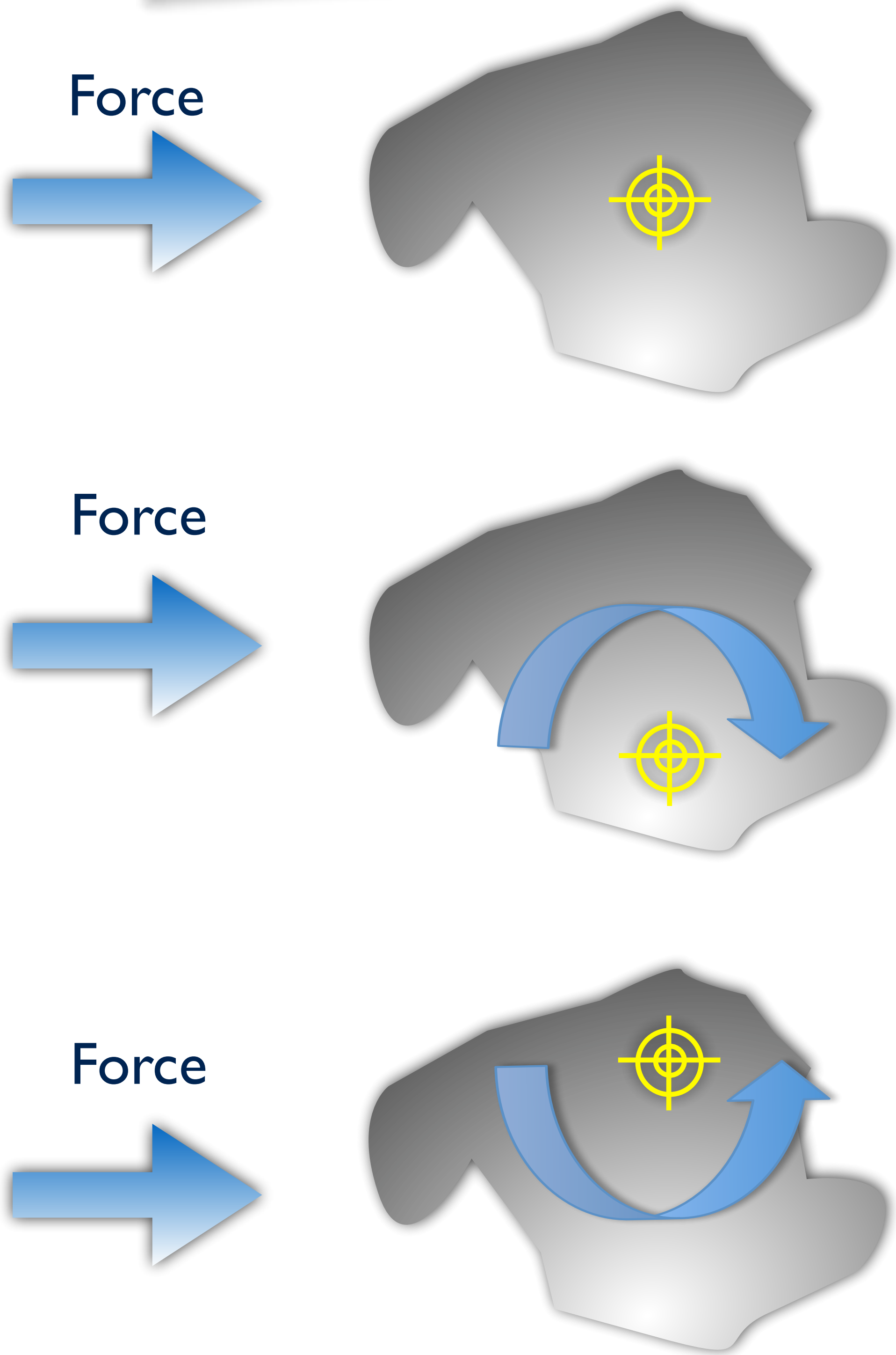
- CR point is based on the estimation or calculate from the experiment therefore, the force system should be monitored according to clinical observation



Clinical implication for Location of CR

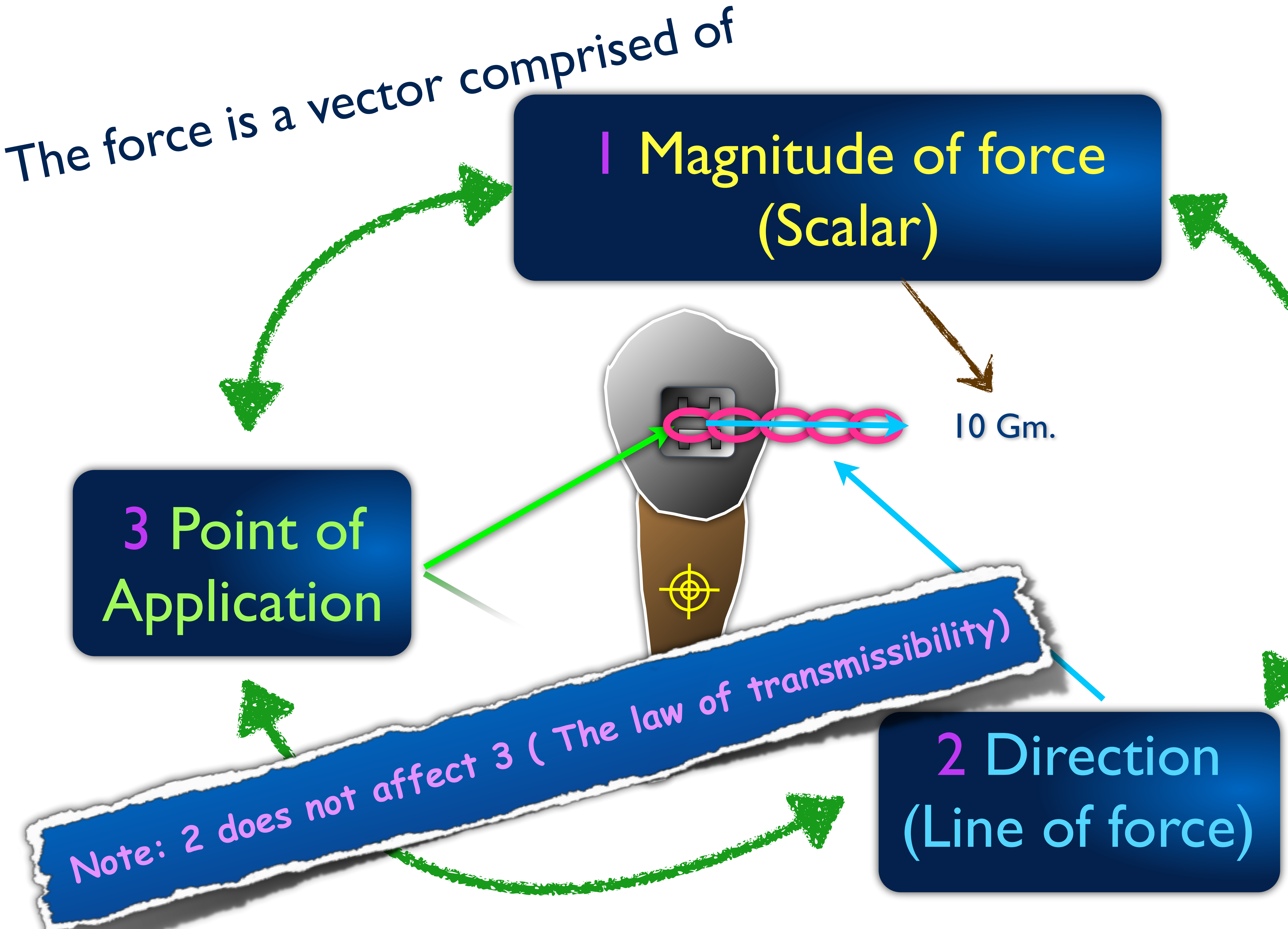
- CR will be about 33% - 40% from the marginal bone depending on the authors
- Practically, localization of CR is based on the estimation therefore, the force system should be monitored according to clinical observation
- CR position varies with root length, root morphology, numbers of root, numbers of teeth and alveolar crest height

Mechanical Concepts in Orthodontics



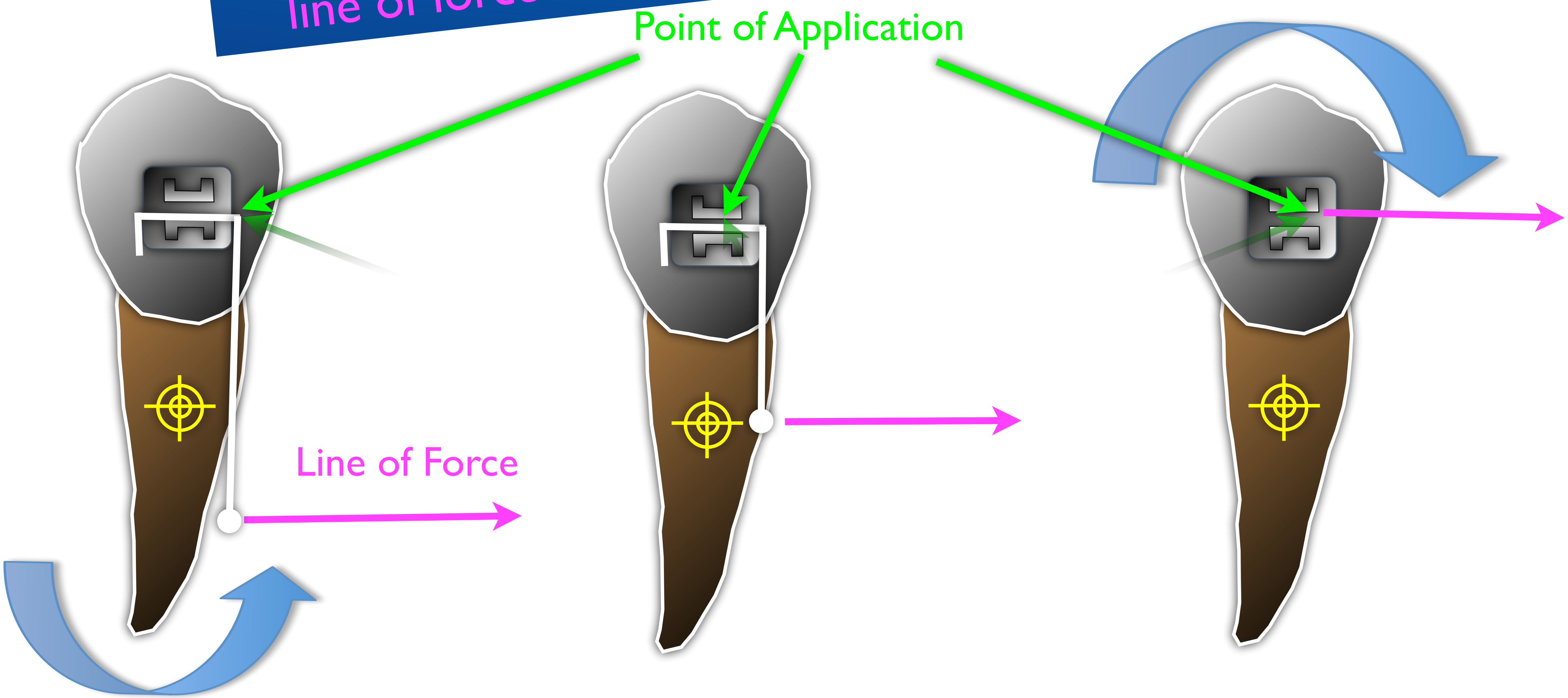
The relationship of the line of force acting on the object to the center of resistance (CR) determines the type of movement expressed

The basic concept of force



Point of Application & Direction (line of force)

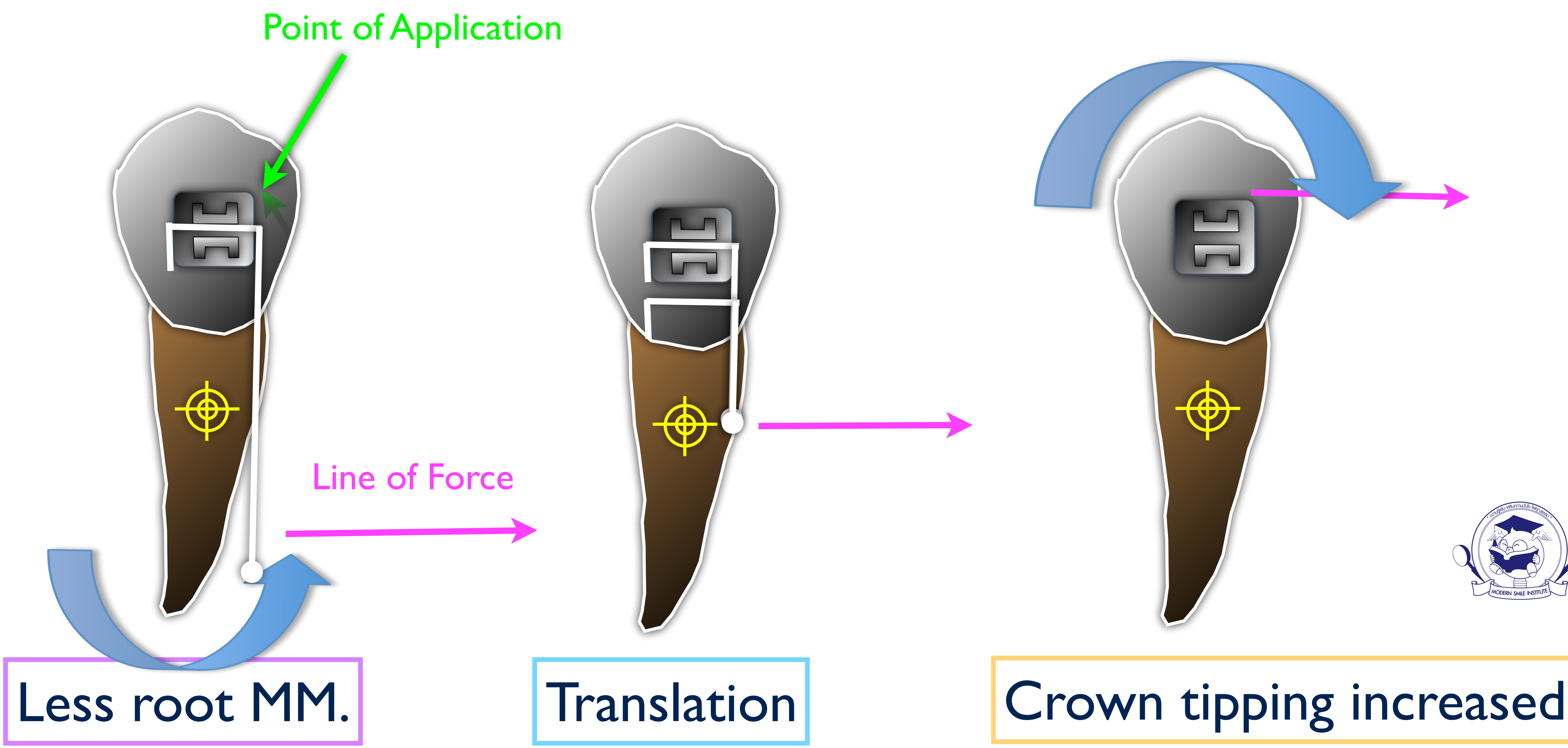
Type of Tooth movement affected by
line of force to CR not point of application



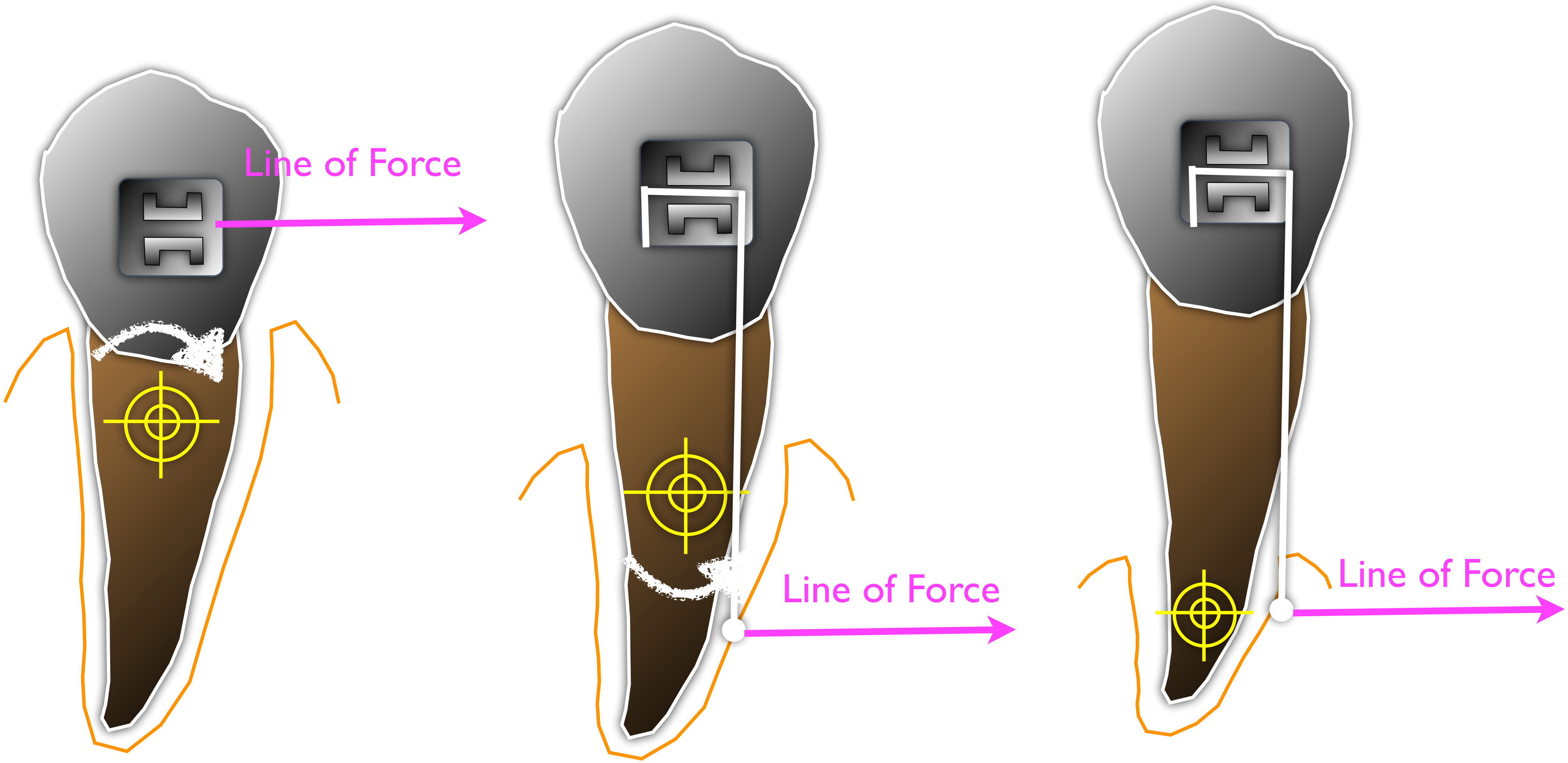
Root MM. Translation Crown tipping

Point of Application & Direction (line of force)

Type of Tooth movement controllable by handling line of force not point of application (BKT position)



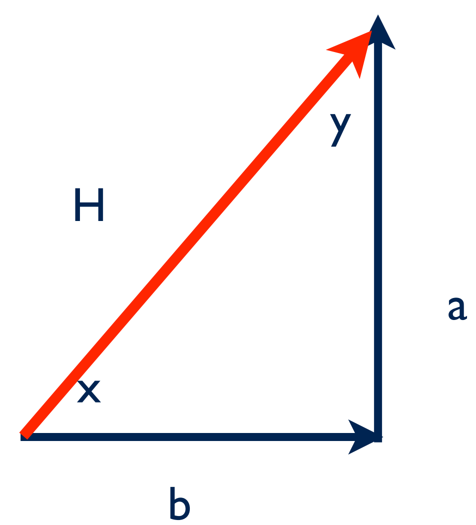
Clinical implication for periodontal cases



Crown tipping   Root MM.   Translation

Handling of Force

Vector Composition



$\text{Sin } x = a/H$ $\quad$ $\text{Sin } y = b/H$

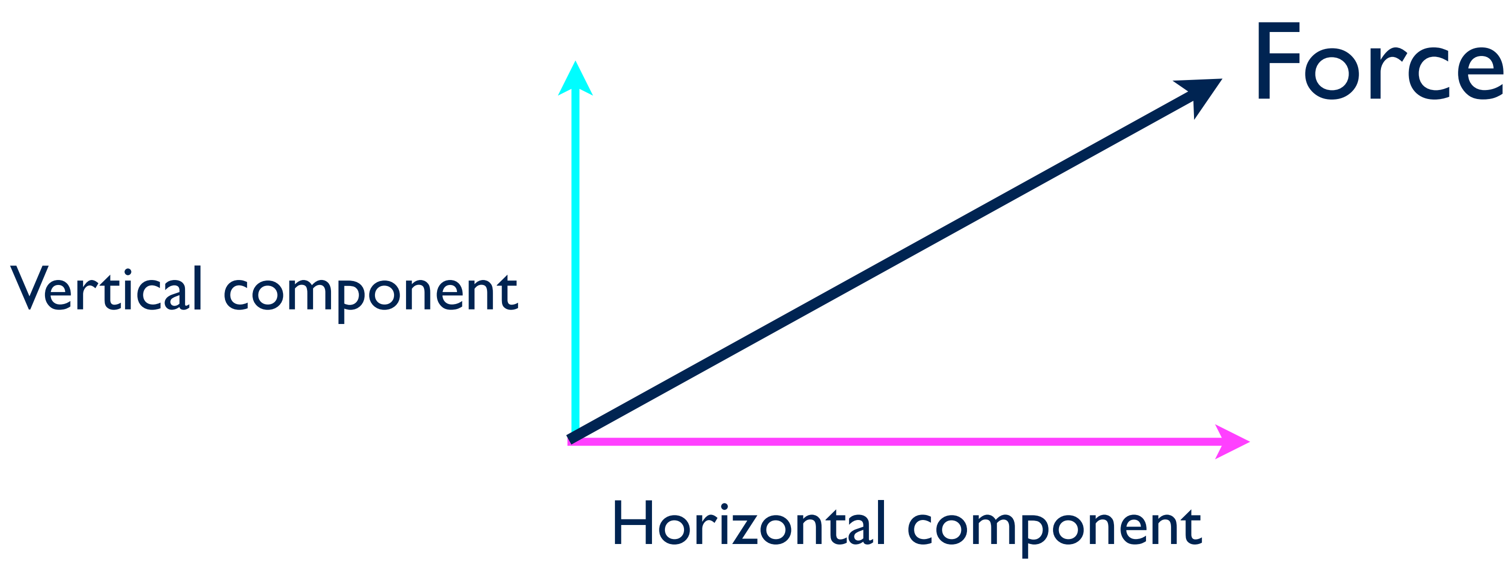
$\text{Cos } x = b/H$ $\quad$ $\text{Cos } y = a/H$

$\text{Tan } x = a/b$ $\quad$ $\text{Tan } y = b/a$

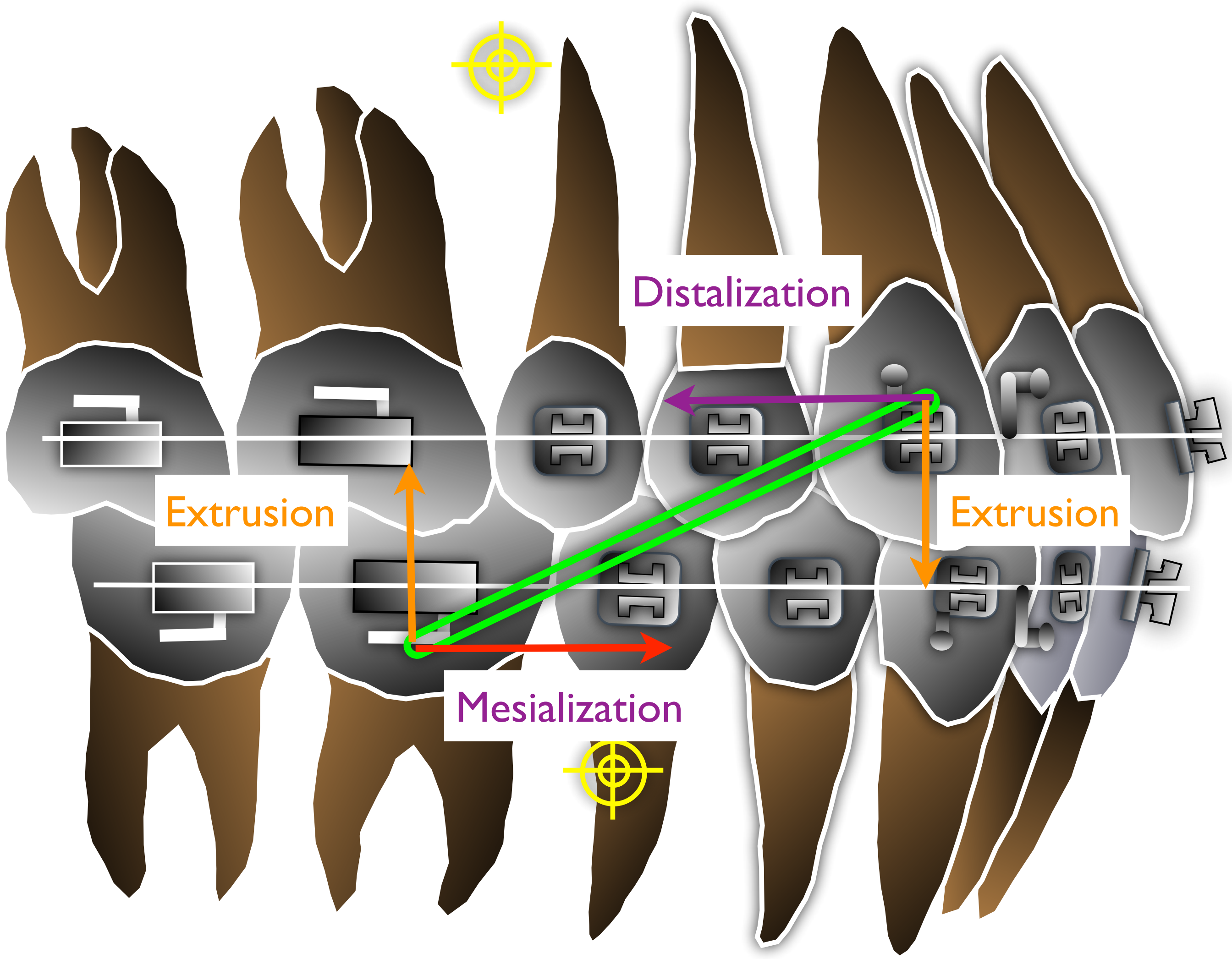
$H^2 = a^2 + b^2$

Vector Decomposition

is a method to decomposed a force into component along the X, Y, Z axes

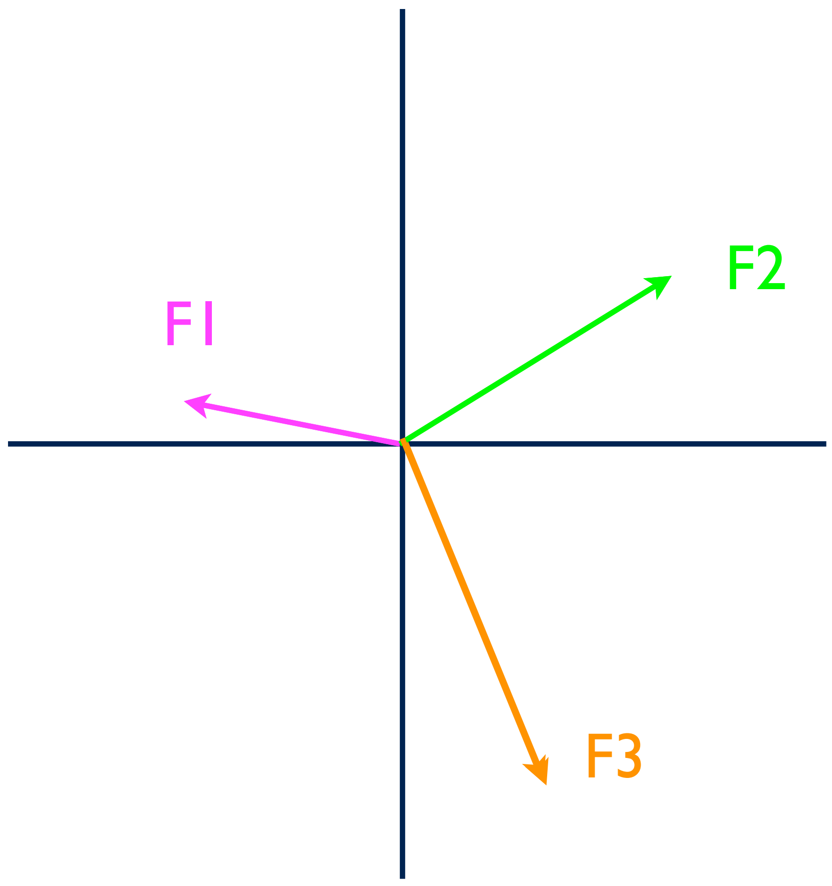


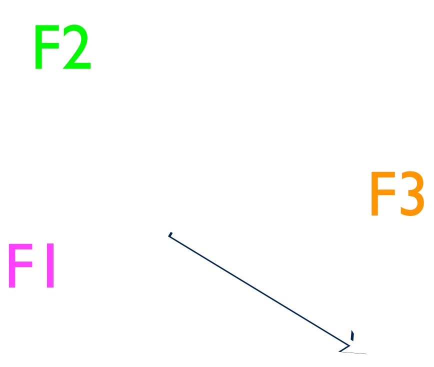
Handling force in orthodontic



Clinically, the determination of the horizontal, vertical, and transverse component of a force can help the understanding of the direction of tooth movement

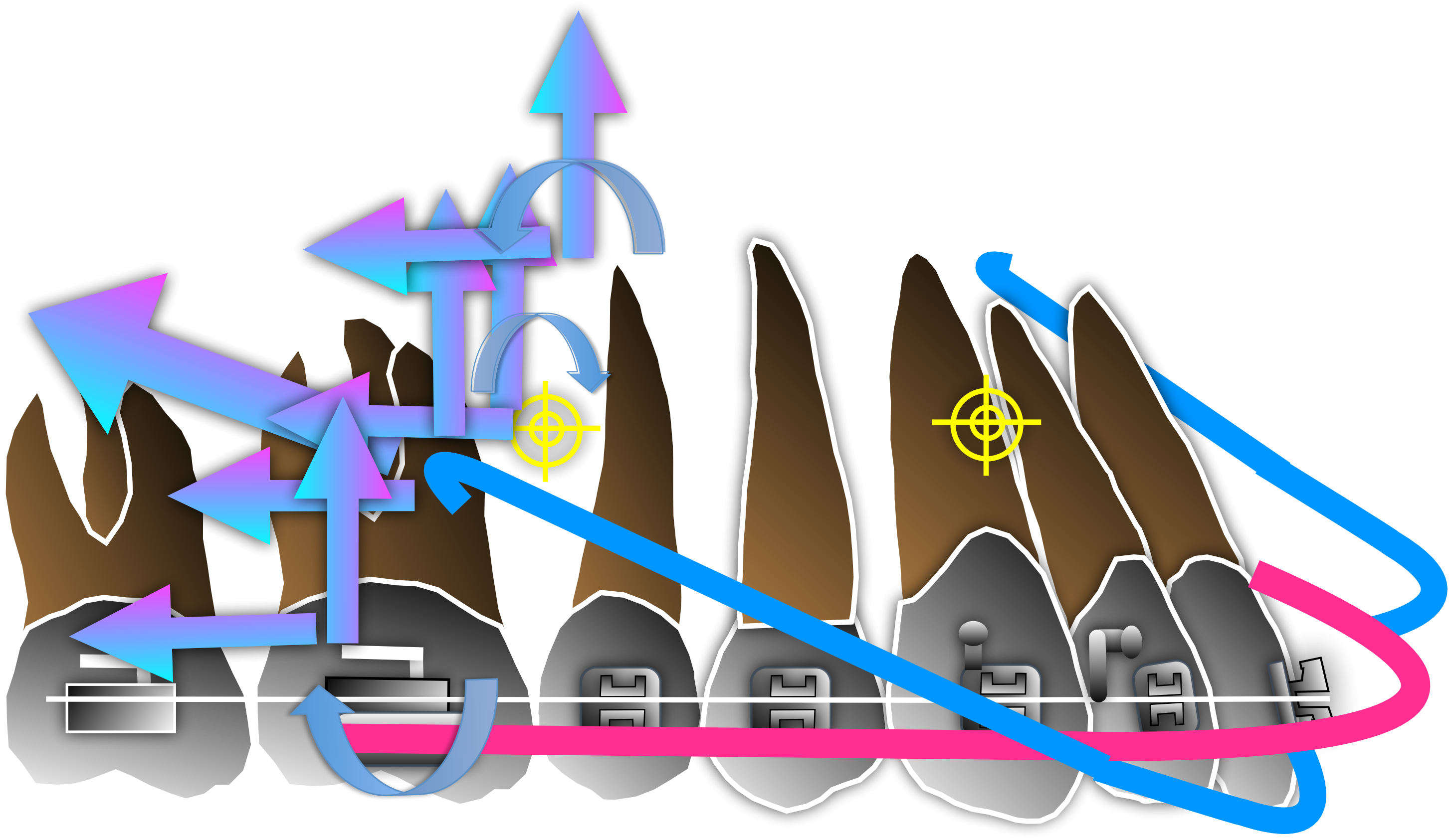
Determination of Resultant Force





Resultant is not coincide with any force
(Magnitude, Point of application, Direction)

- Magnitude of force (Scalar)= the length of the line
- Point of Application = Center
- Direction (line of force)



line of force
composed and decomposed vectors

Type of Tooth Movement in Term of mechanic

- Translation : Force passing through CR produces all points of the tooth move an equal distance in the same direction.

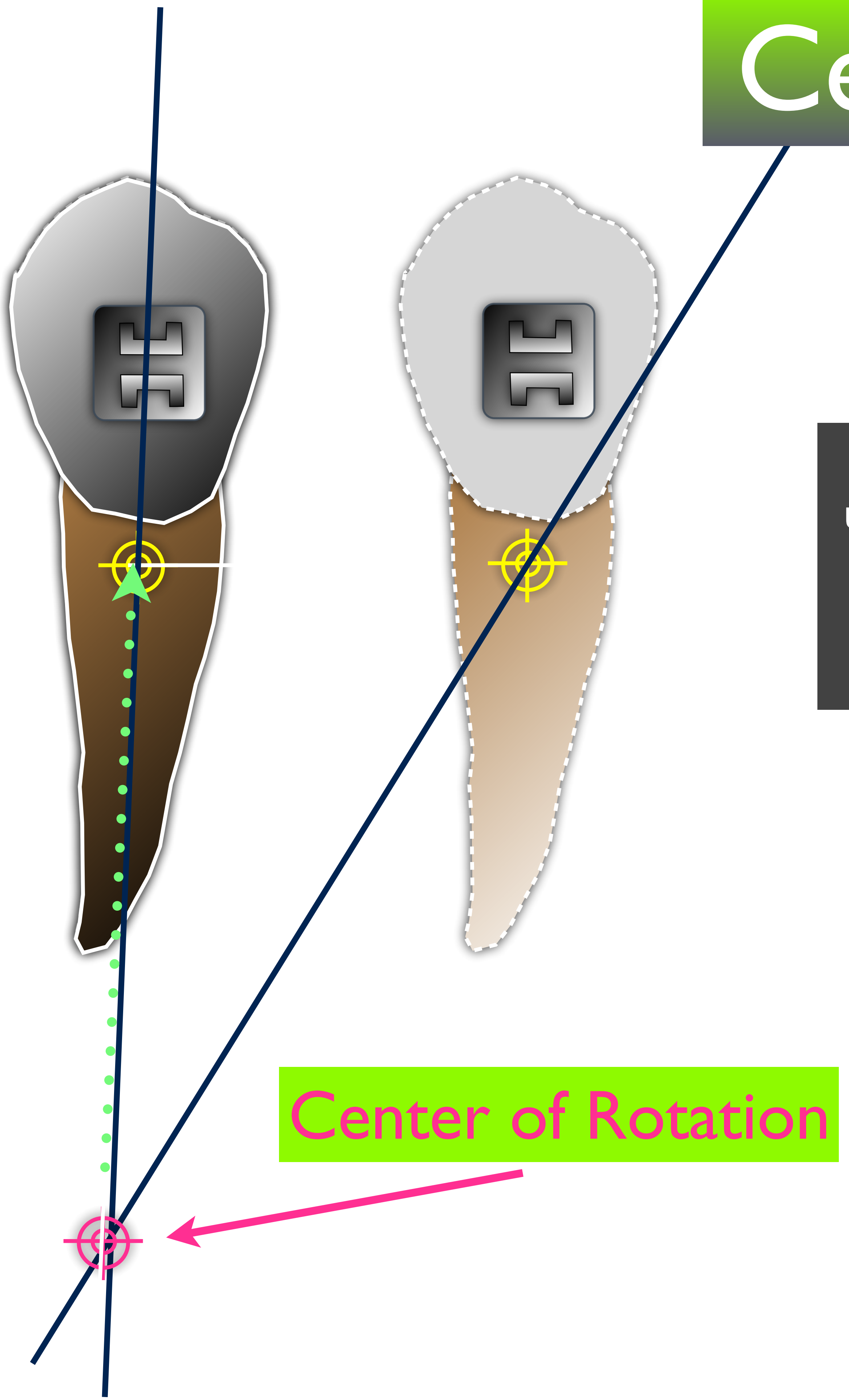
- Pure Rotation : Movement of all points around the CR as being a center of circle (Couple)

- Combination : Not pure rotation and pure translation

Type of Tooth Movement in Biomechanic Term

Translation Pure Rotation Combination

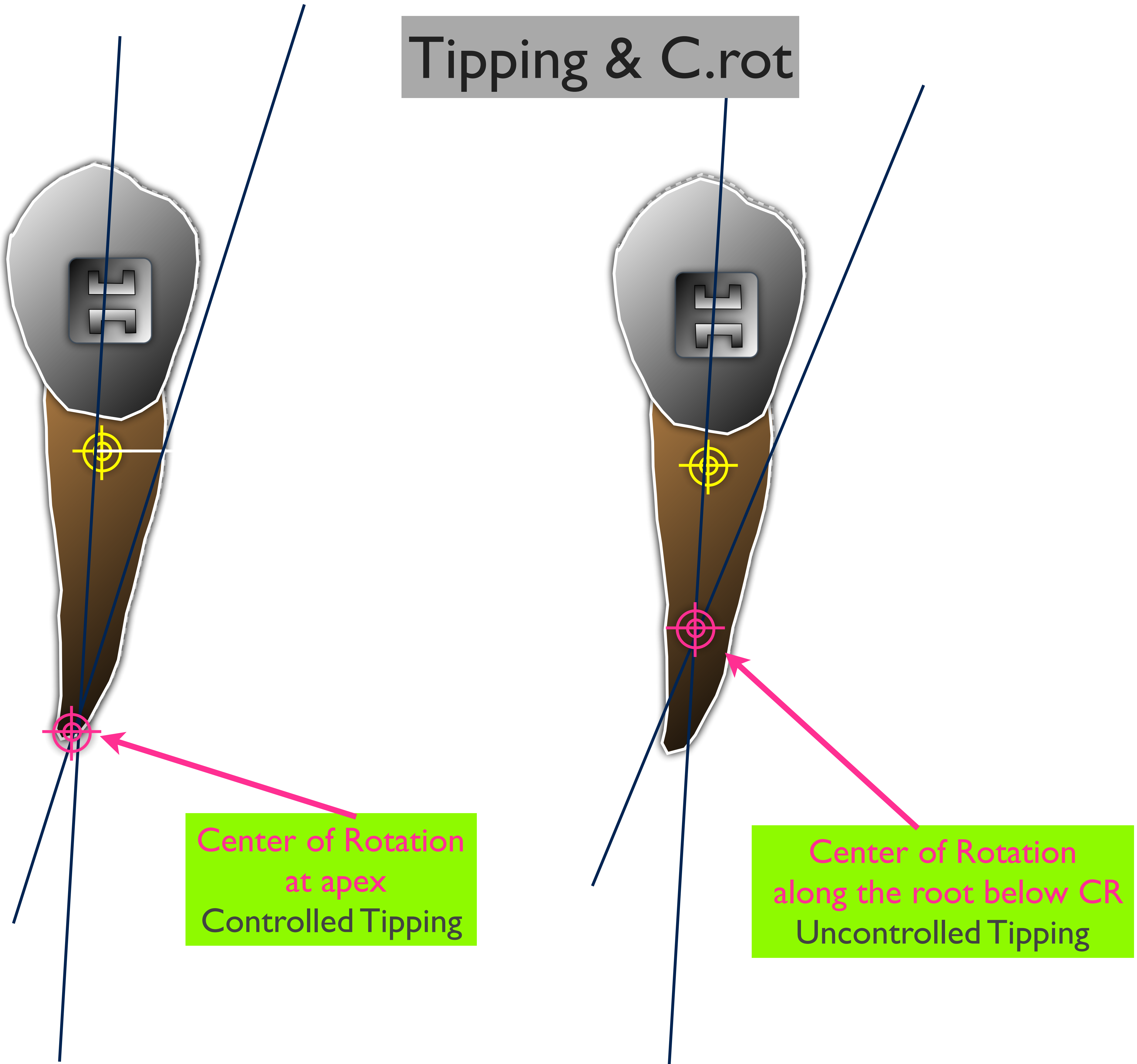
Center of Rotation

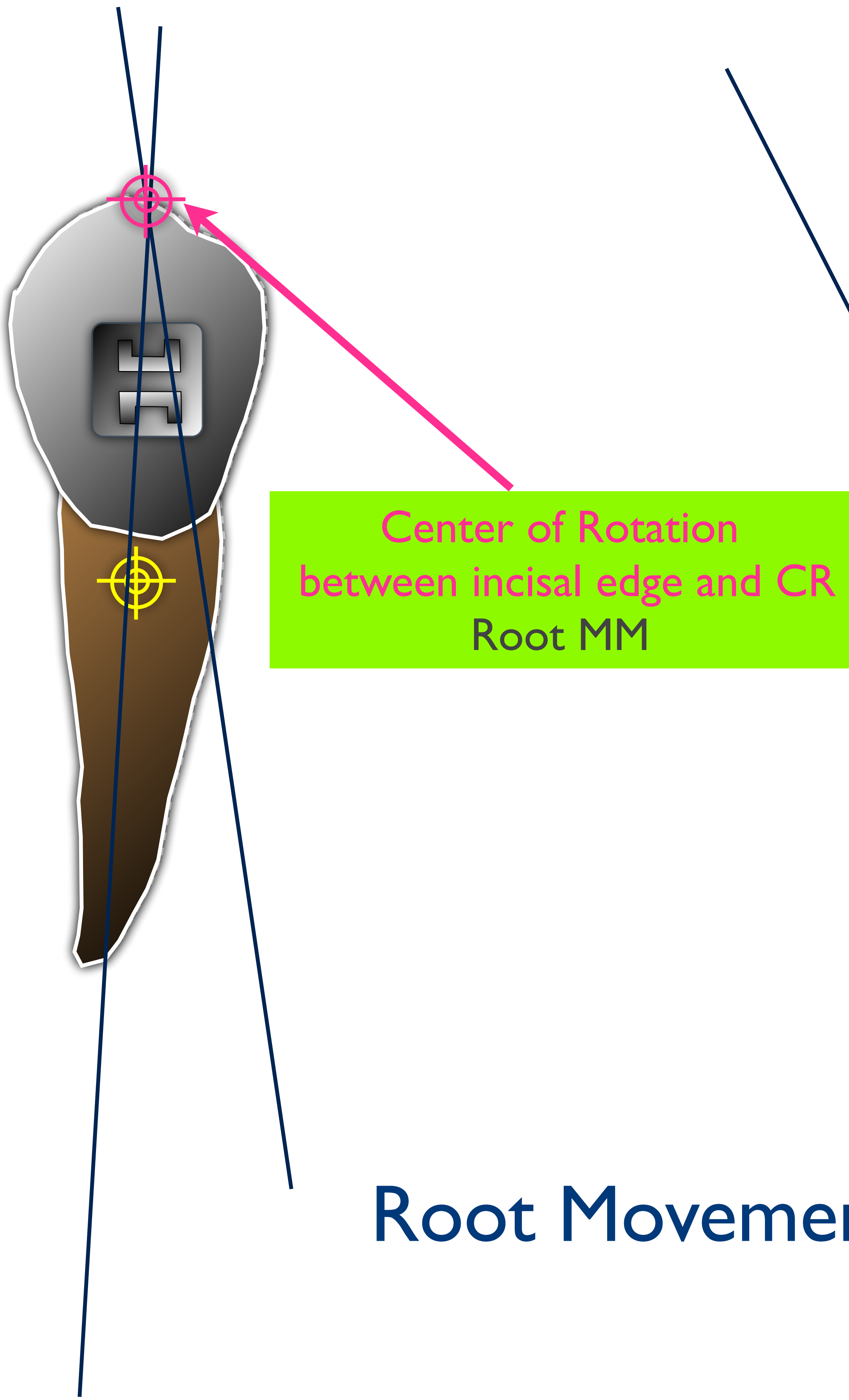


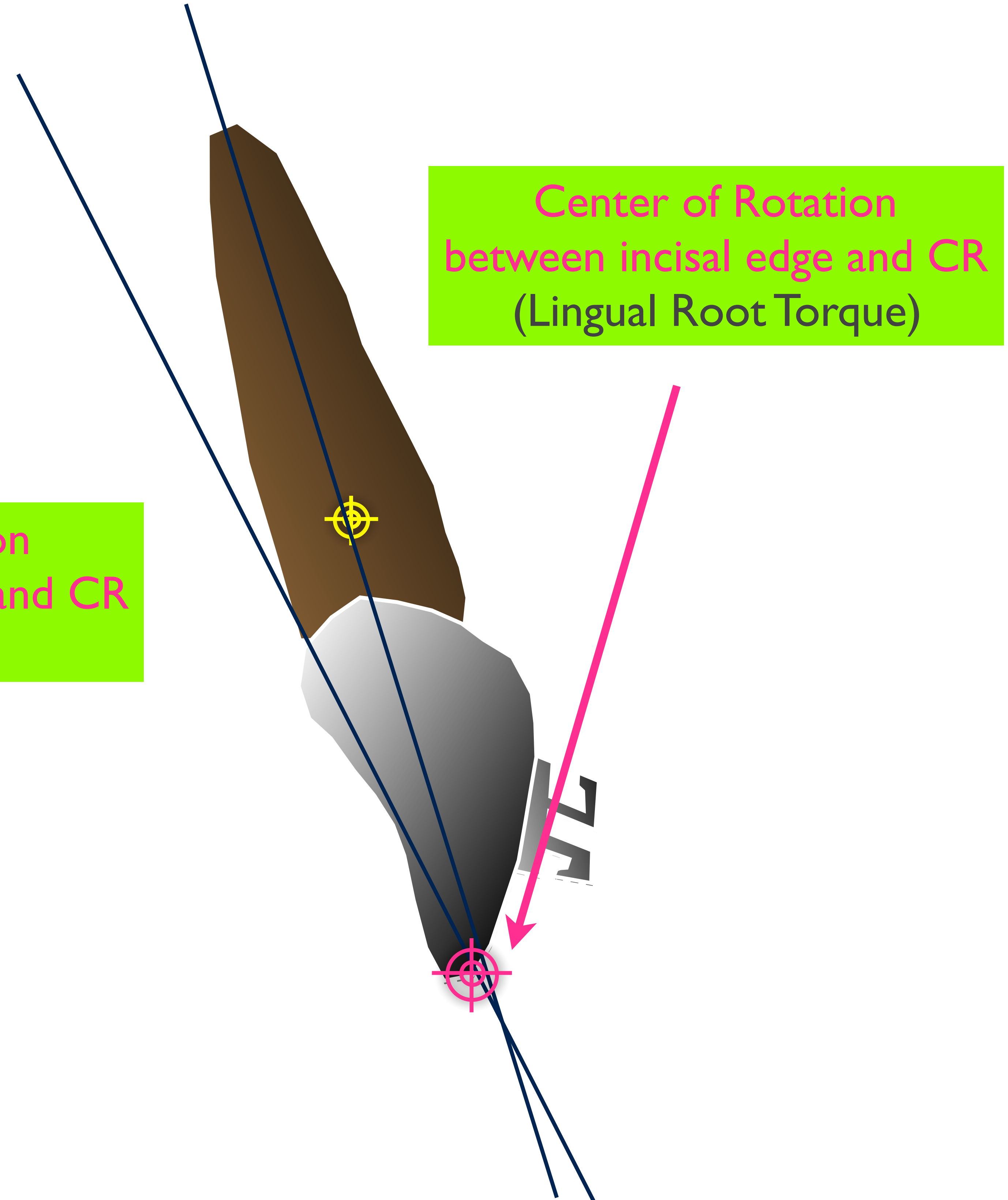
Combination of pure rotation and translation usually occurs in orthodontic clinic, therefore, there must be the exact point to determine type of tooth movement which is the center of rotation

Movement of points of the tooth along the arc of a circle. The center of the circle is the center of Rotation

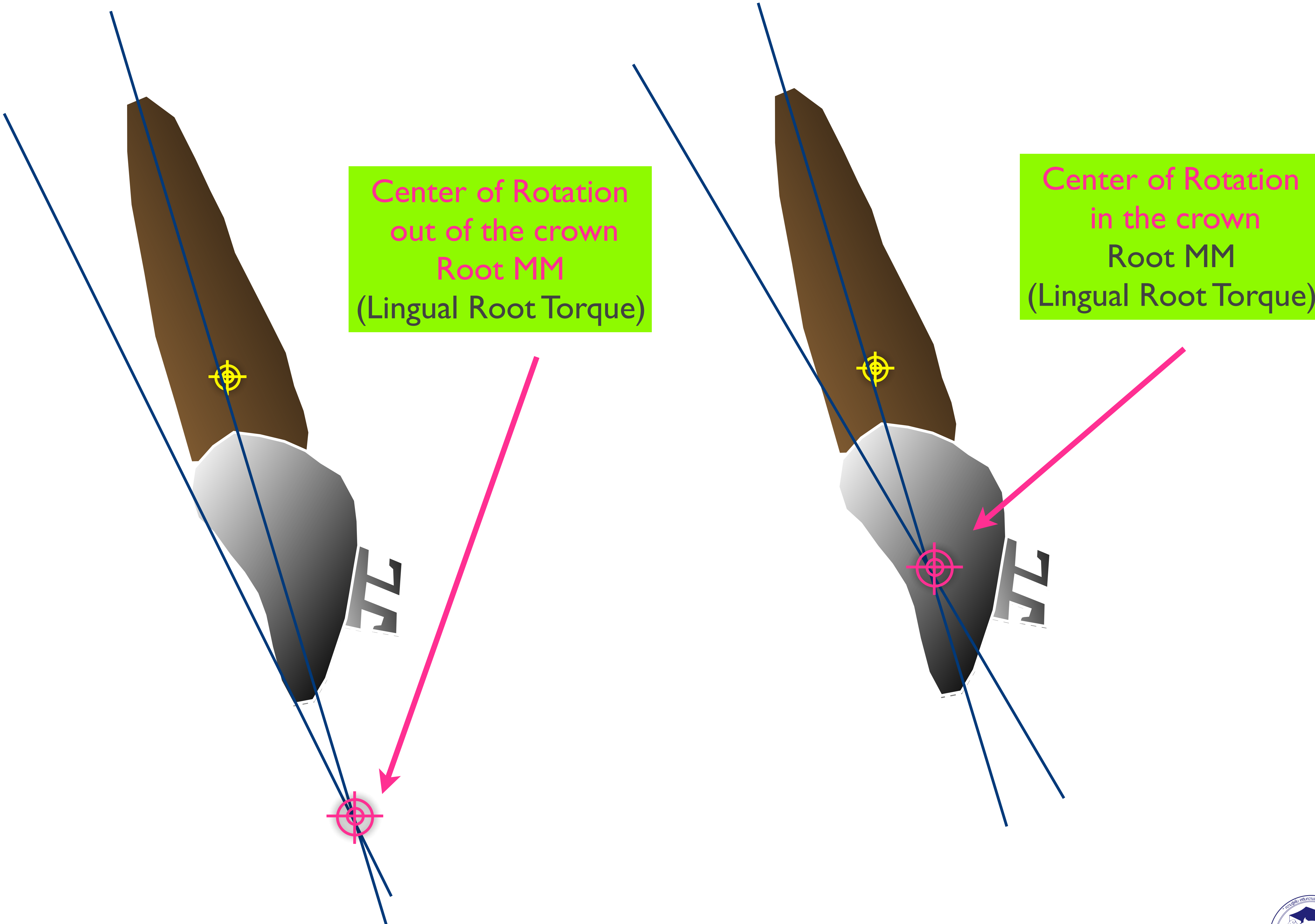
Tipping & C.rot



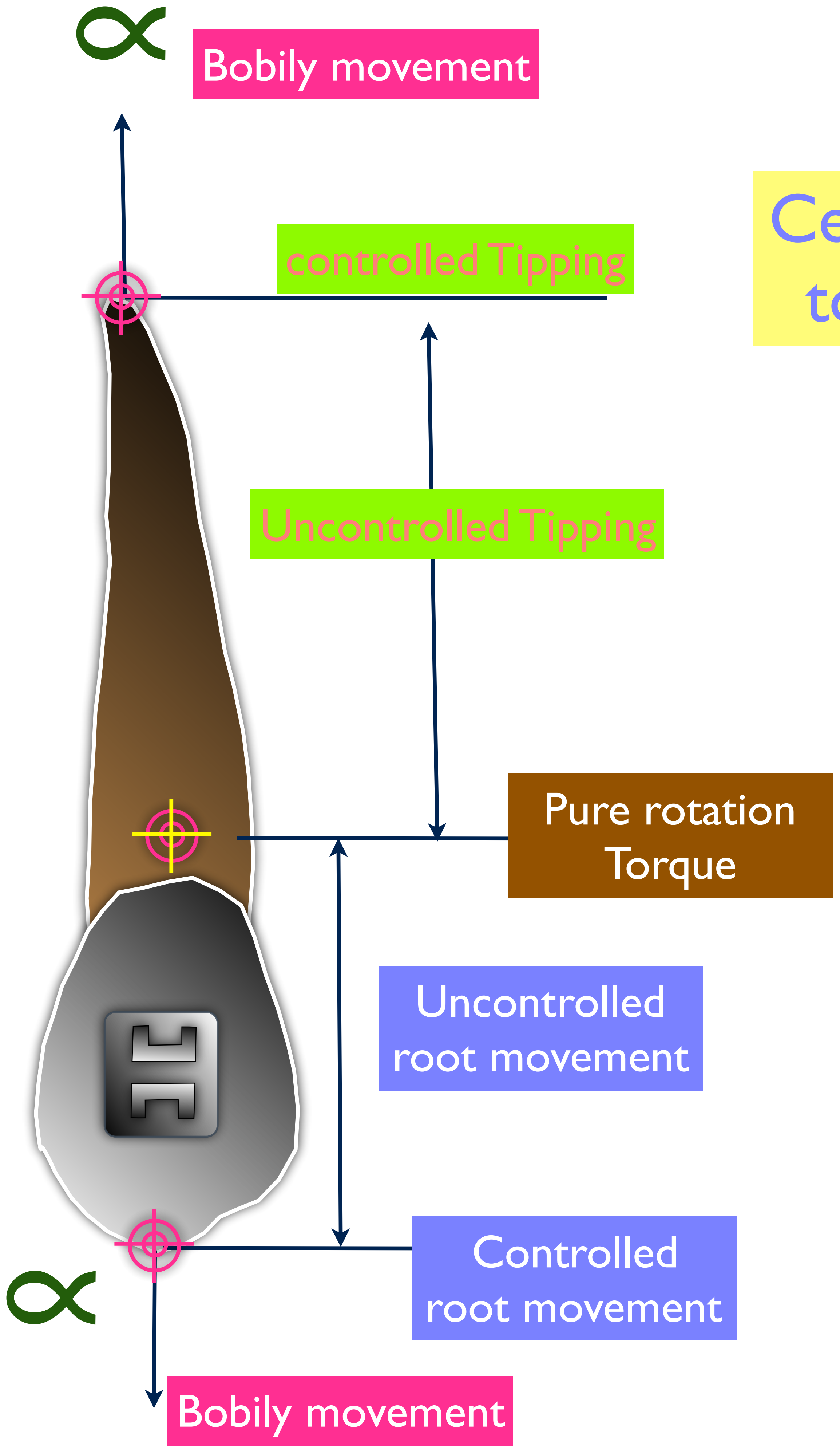




Root Movement (Torque)


Center of Rotation
out of the crown
Root MM
(Lingual Root Torque)
Center of Rotation
in the crown
Root MM
(Lingual Root Torque)

Center of Rotation (C.rot)and type of tooth MM. in Term of Orthodontics



Clinical implication for C.rot

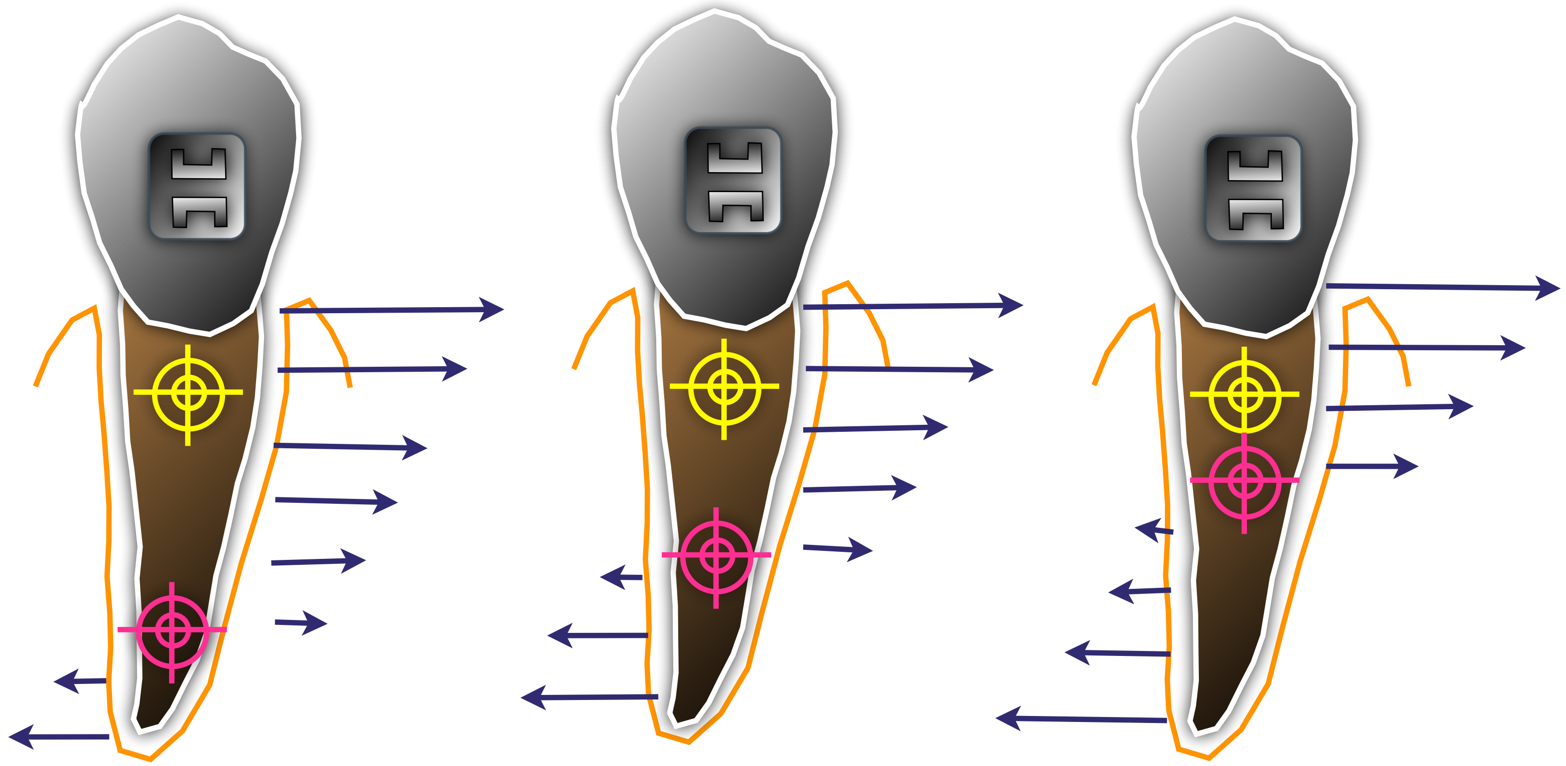
- determined from its initial and final position
- can be at any position on or off a tooth
- can be used to describe type of tooth movement

Types of object movement (position of C.rot) in Orthodontic term Vs Biomechanics term

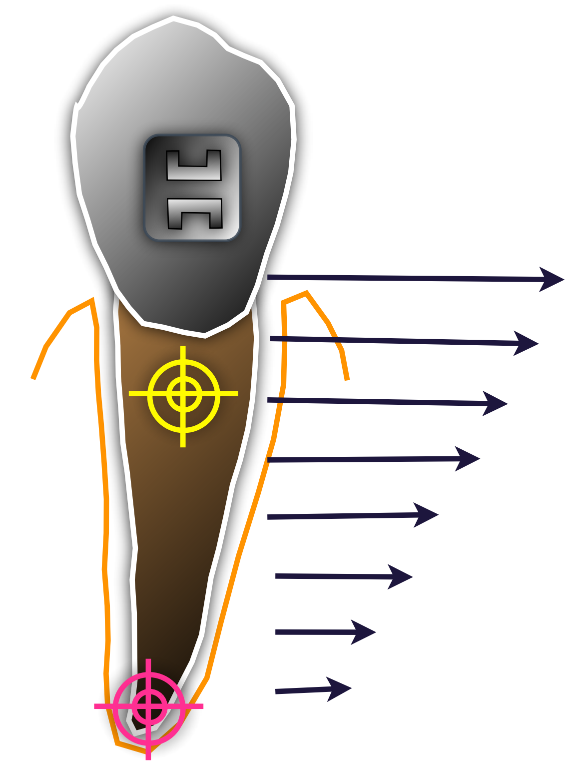
Position of C.rot	Biomechanic	Orthodontic
Infinity	Translation	Bodily MM
Apex	Tipping	controlled Tipping
Apical to CR	Combination	Uncontrolled Tipping
CR	Pure Rotation, Couple	1st, 2nd, 3rd order bend (Toe in-out, tipping,artistic bend, Tip back, Torque)
CR - incisal edge	Root MM	Lingual / Buccal Root Torque
Incisal edge	Root MM	Lingual / Buccal Root Torque

Tipping

Crown MM. is greater than root MM.

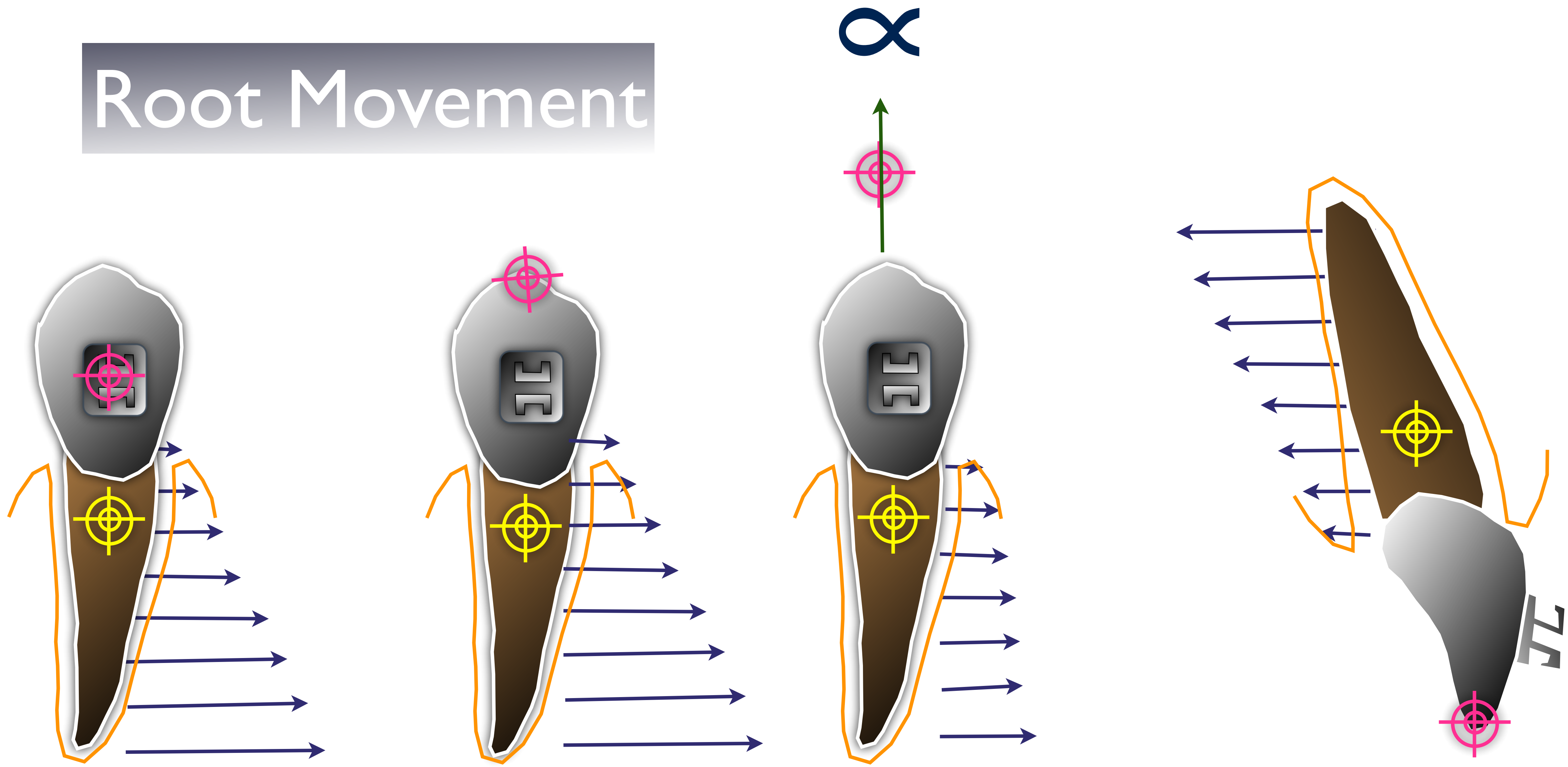


Uncontrolled Tipping



Controlled Tipping

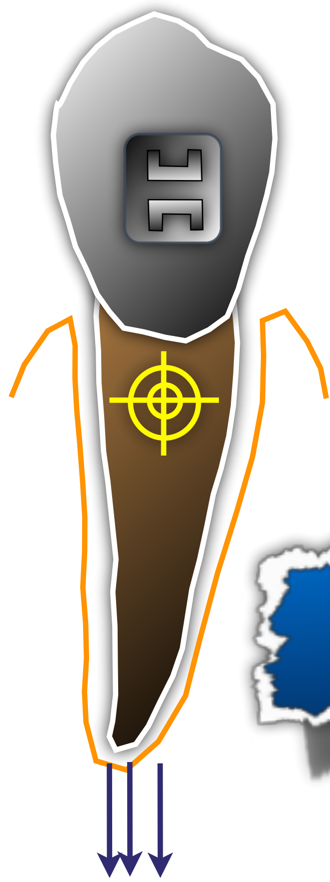
Root Movement



Root MM. is greater than crown MM.

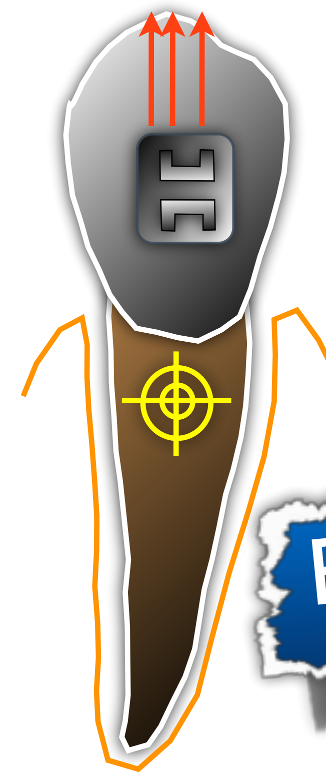
Root movement must be manipulated carefully if inevitable to avoid root resorption

Tooth movement in vertical plane



Intrusion

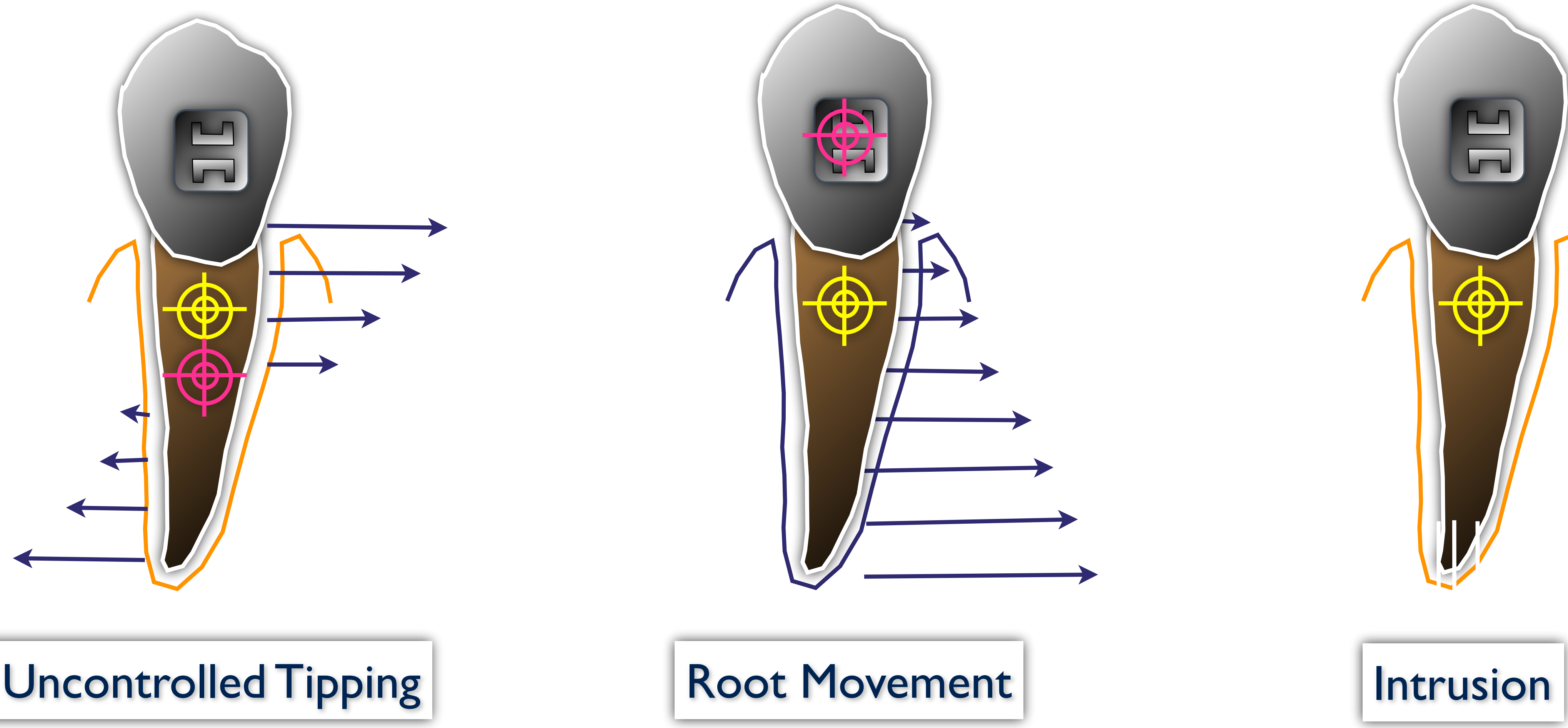
must be manipulated carefully if inevitable to avoid root resorption



Extrusion

is the easiest type of tooth movement to occur

Why is the type of tooth movement so important ?



-Root resorption
-Root pinching out cortical bone

Very ๆๆๆ
Light Force

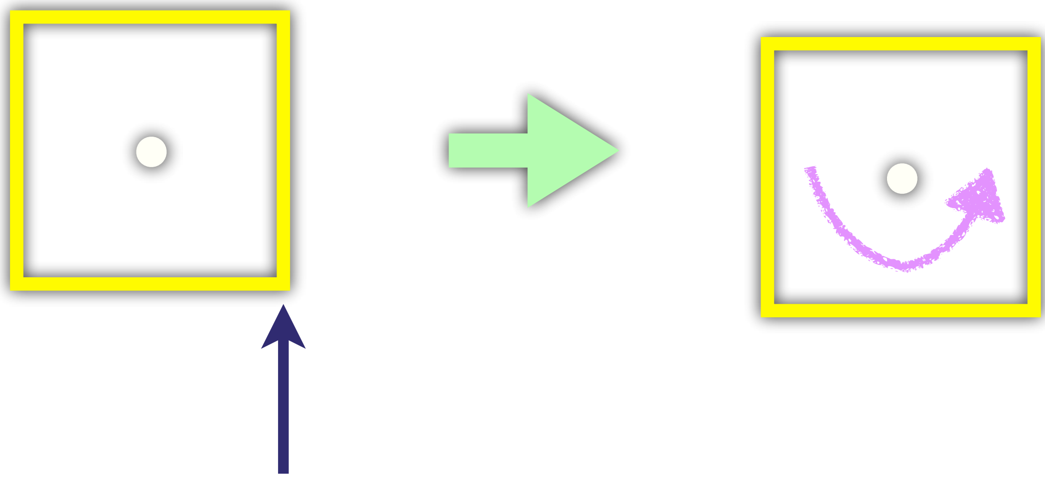
Moment of Force Vs Moment of Couple

- Moment of force (M_f): Magnitude of single force not parallel through CR X perpendicular distance from the line of action to CR. (C.rot is at anywhere)

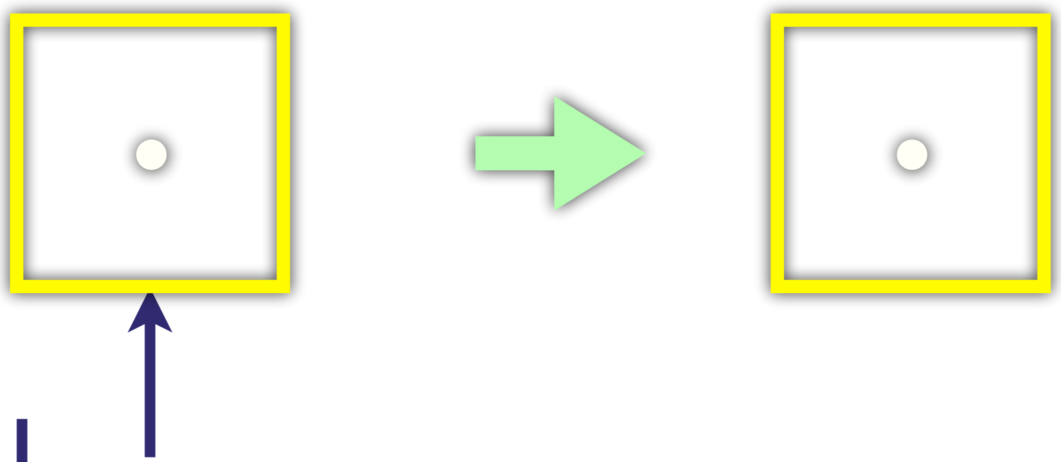
- Couple force : Consists of 2 forces of equal magnitude with parallel but non-colinear lines of action and opposite senses

- Moment of couple (M_c): Magnitude of one of the forces X the perpendicular distance between them ($C._{rot}$= CR)

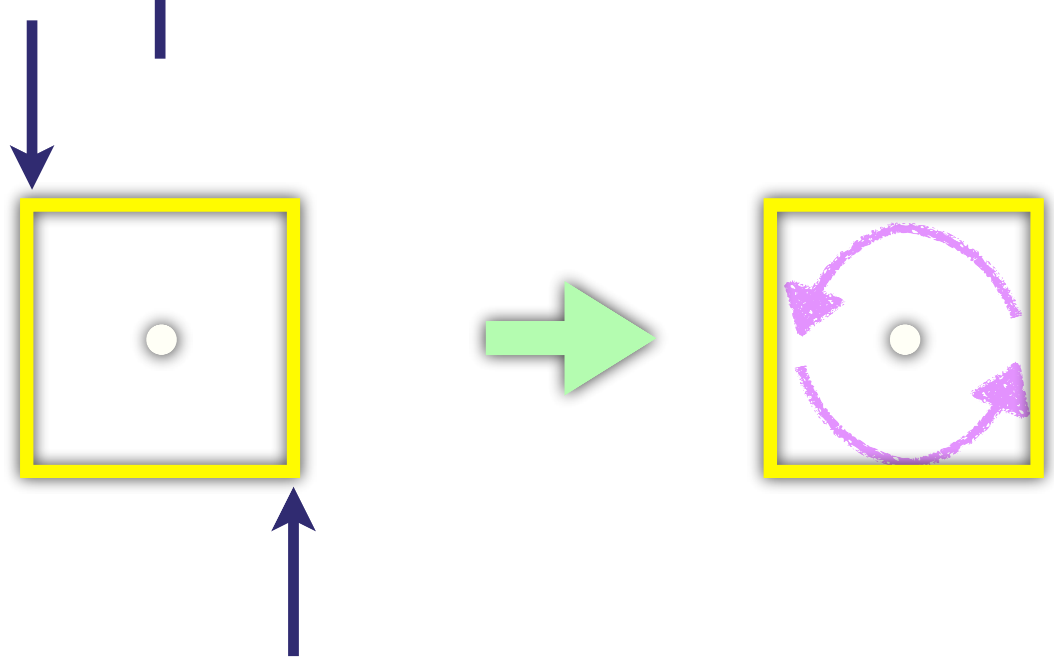
Moment of Force Vs Moment of Couple



- Moment of force (M_f): Magnitude of single force not parallel through CR X perpendicular distance from the line of action to CR. (C.rot is at anywhere)



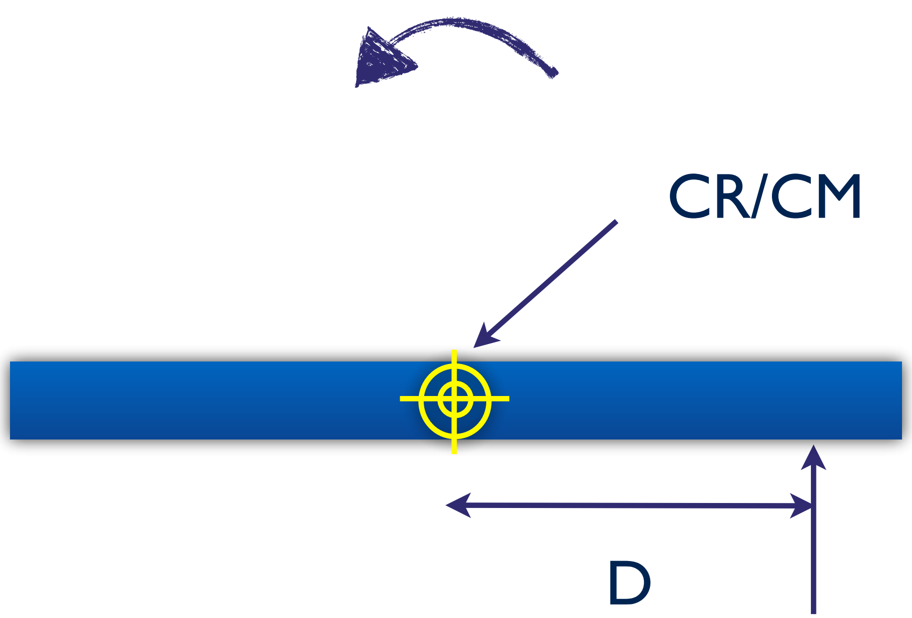
- No Moment of force or Couple



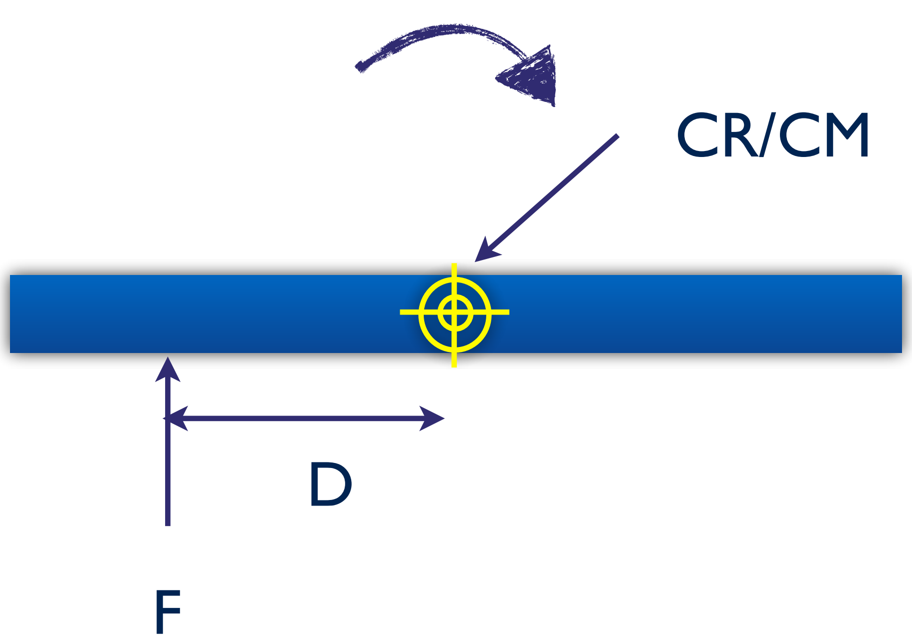
- Couple : Consists of 2 forces of equal magnitude with parallel but non-colinear lines of action and opposite senses

Moment of force (M_f)

Magnitude of single force not parallel through CR(CM) X perpendicular distance from the line of action to CR. (C.rot is at anywhere)



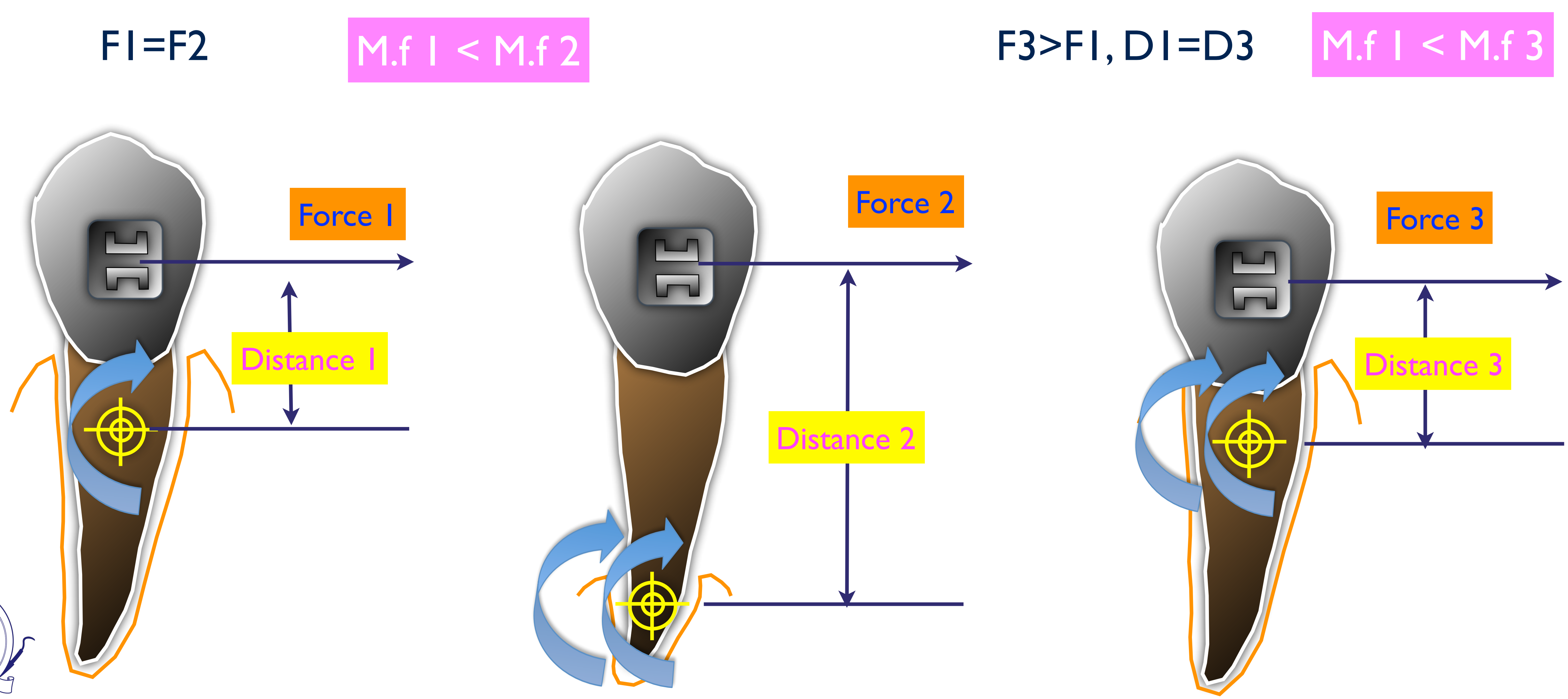
Type of Moment	Moment	Sense	Center of rotation
Moment of Force	Force X Distance (Newtons - millimeter)	**Translation &Counter clockwise** rotation	Next to CR at the left side



Type of Moment	Moment	Sense	Center of rotation
Moment of Force	Force X Distance (Newtons - millimeter)	**Translation &Clockwise** rotation	Next to CR at the right side

Clinical implication of Moment of force (M_f)

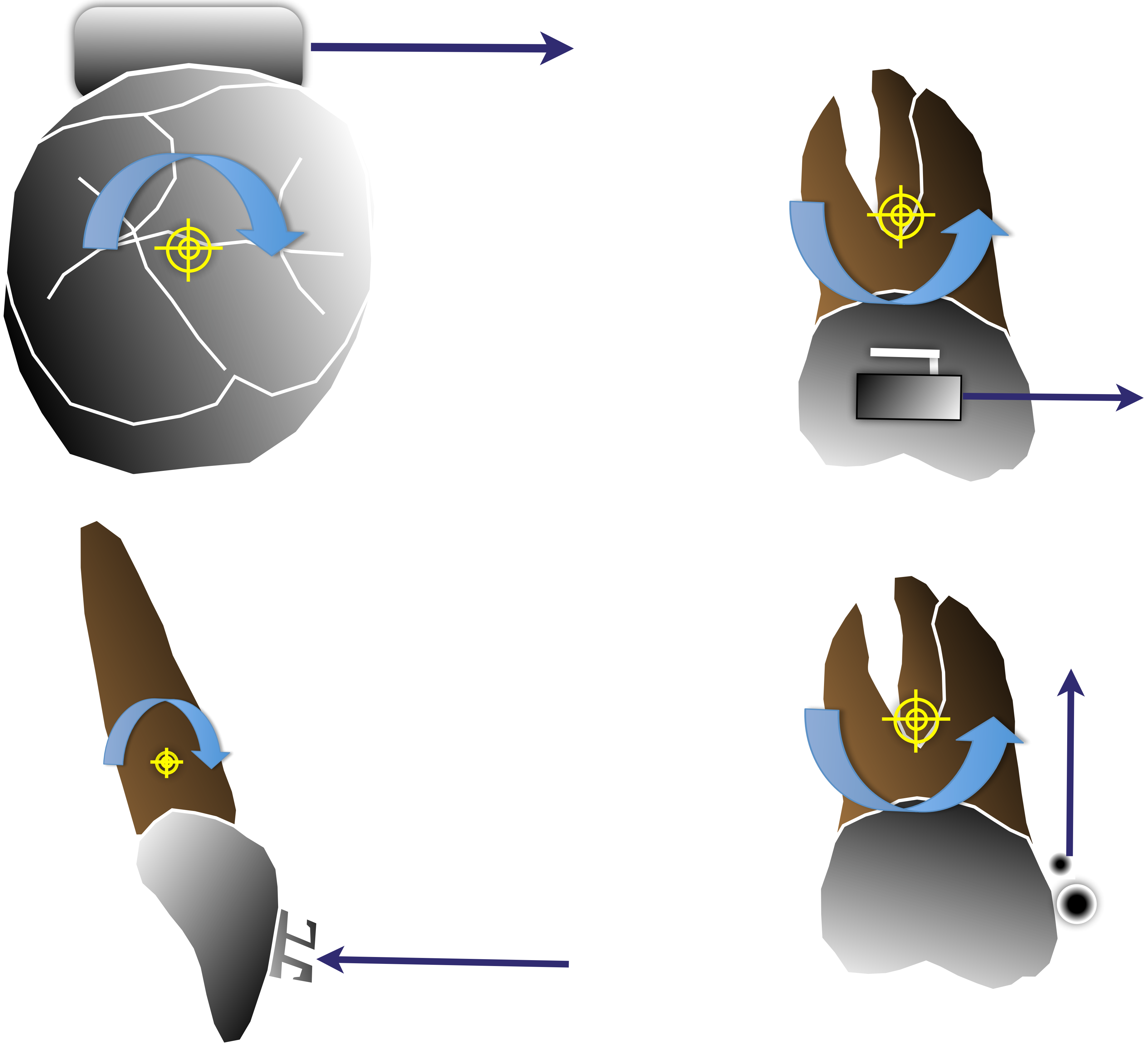
M.f = Force X Distance (Newtons - millimeter)



Pay very much attention in patient with alveolar bone loss

The more the force, the more the moment of force

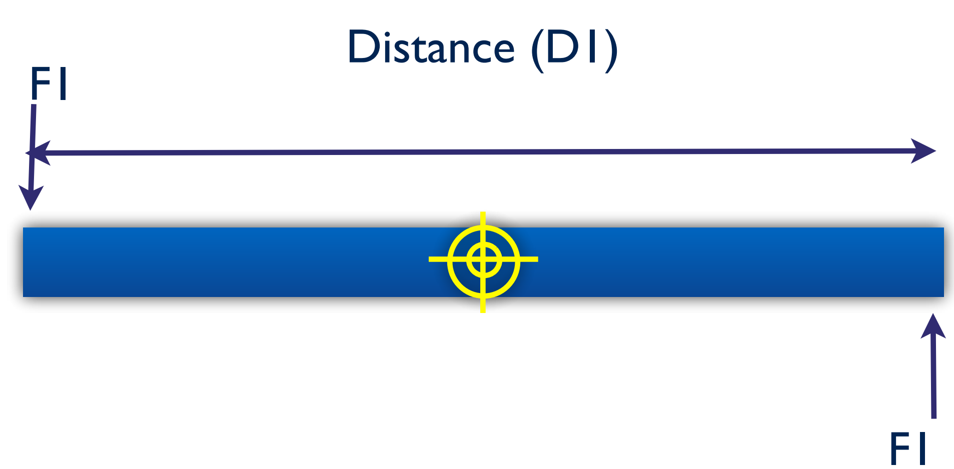
Moment of force commonly occurred in orthodontic clinic



Moment of Couple

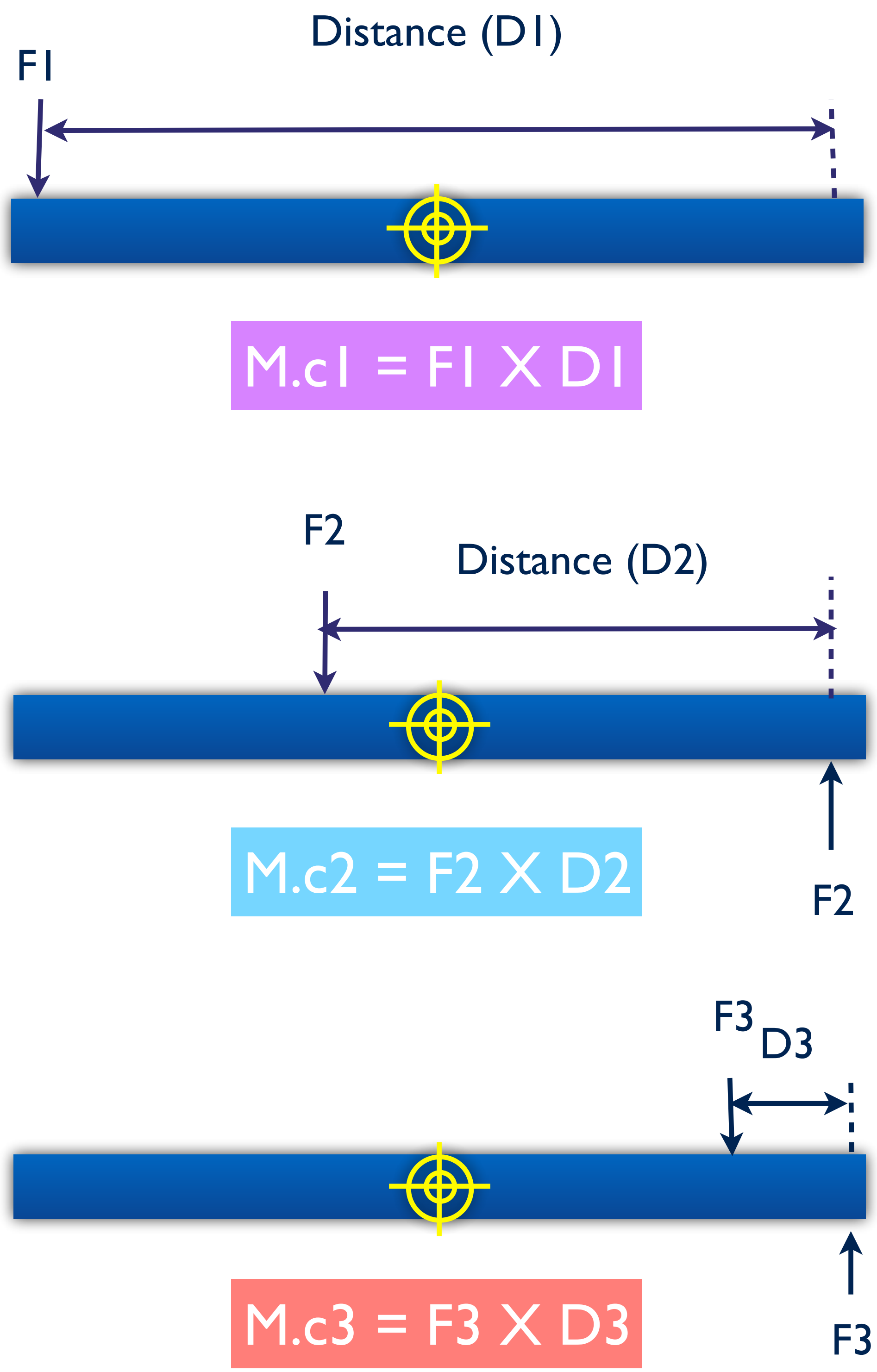
Two parallel forces of equal magnitude acting In opposite directions and separated by a distance. (No translation)

Moment of Couple = Force X Distance (Newtons-mm.)



Center of Rotation = The center of resistance=Pure rotation

Moment of Couple

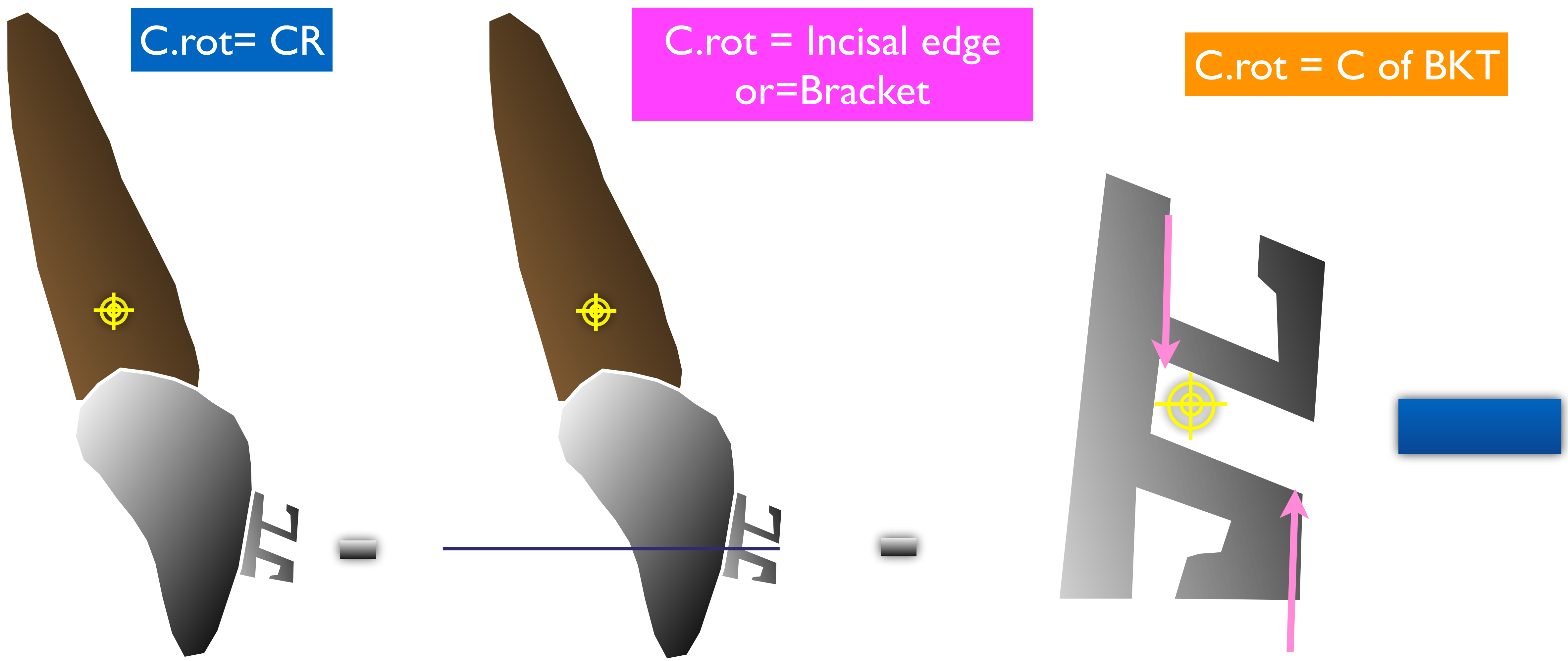


Center of Rotation
= CR
= CM

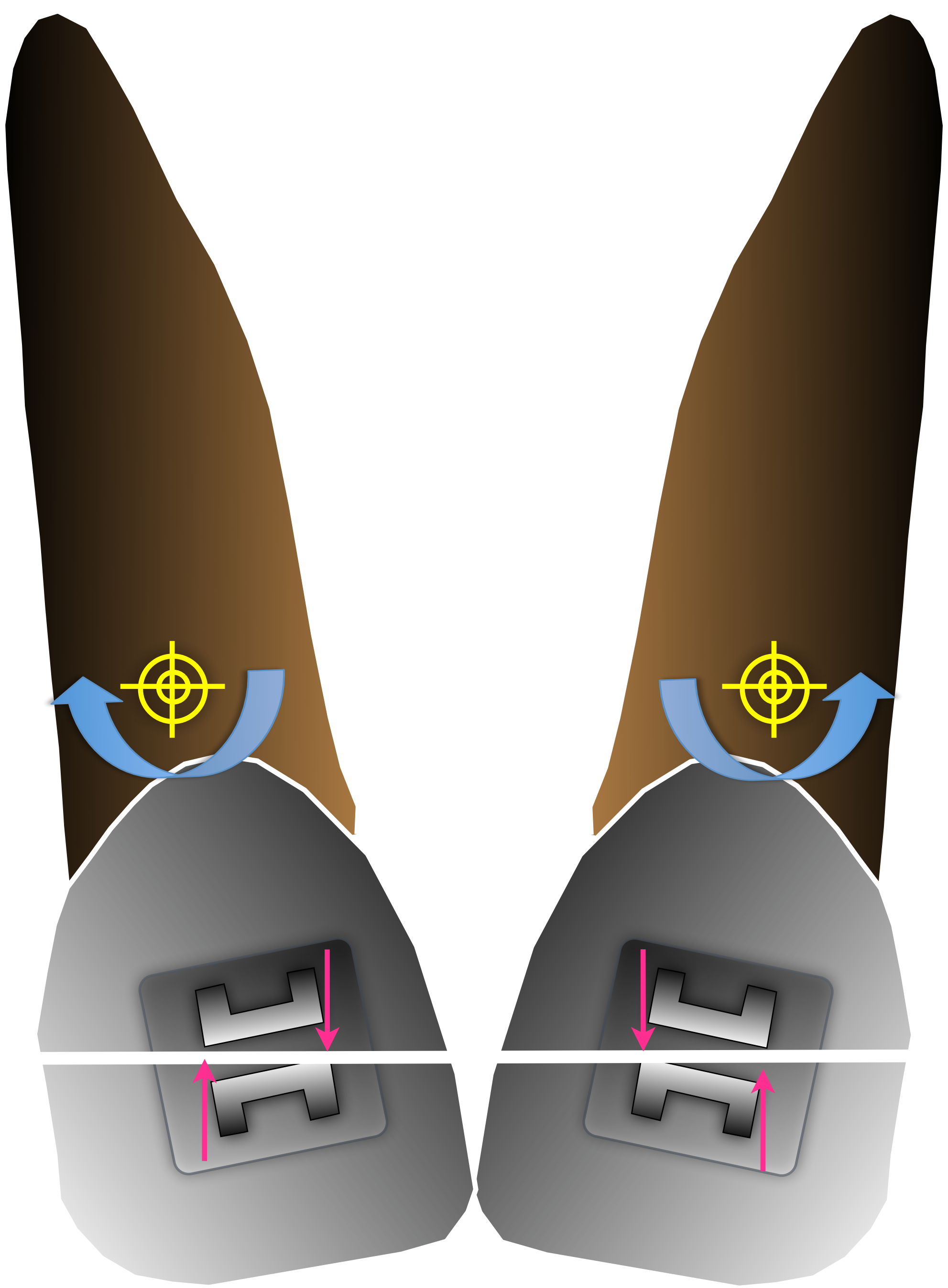
What does it mean ?

Producing rotation at CR regardless of the location of forces applied.

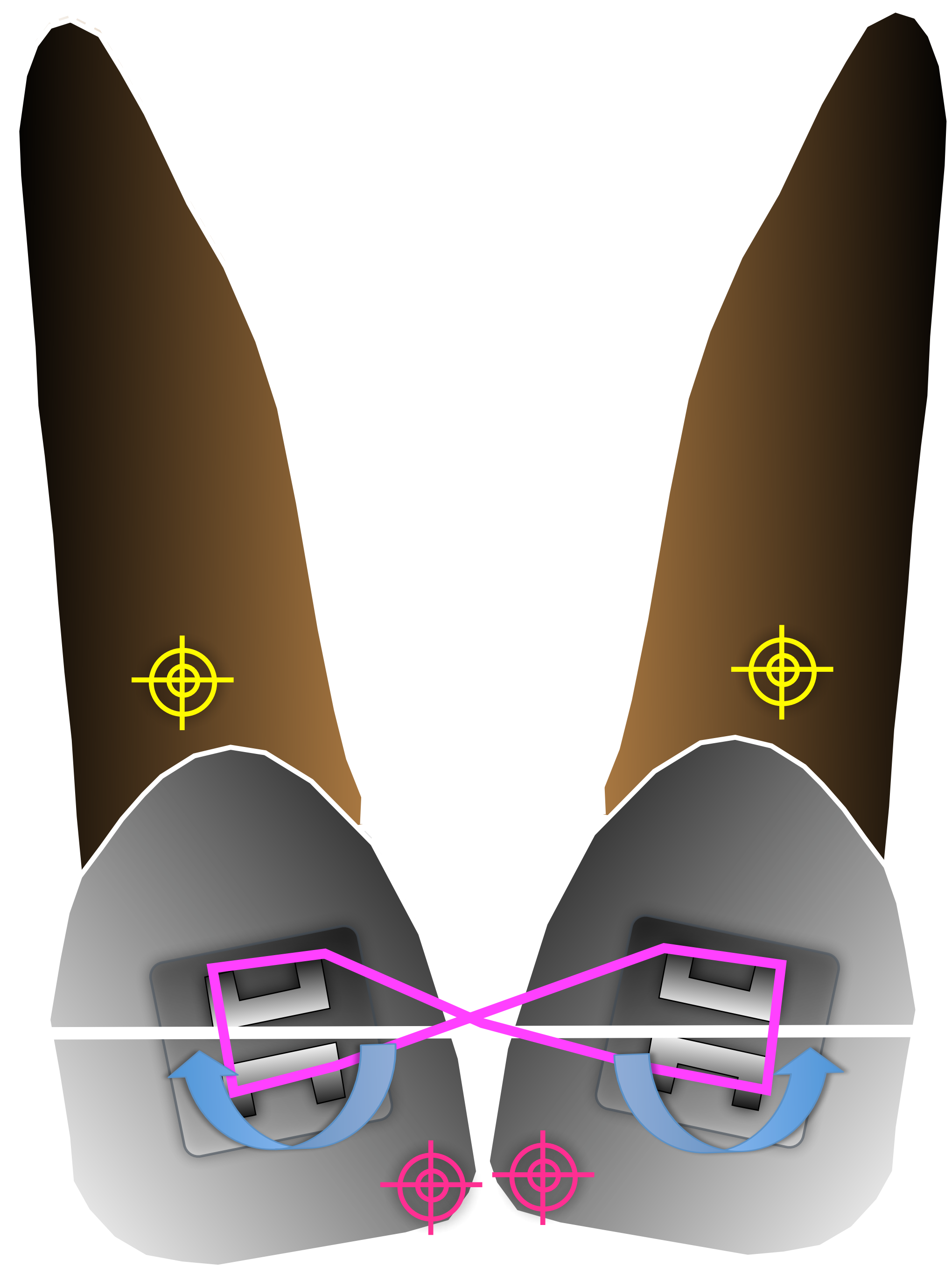
What does we learn from the concept of Moment of Couple in Orthodontics ?



The 1/1 will be proclined when 16 x22 NiTi has been used without enmasse or cinch back in the leveling stage

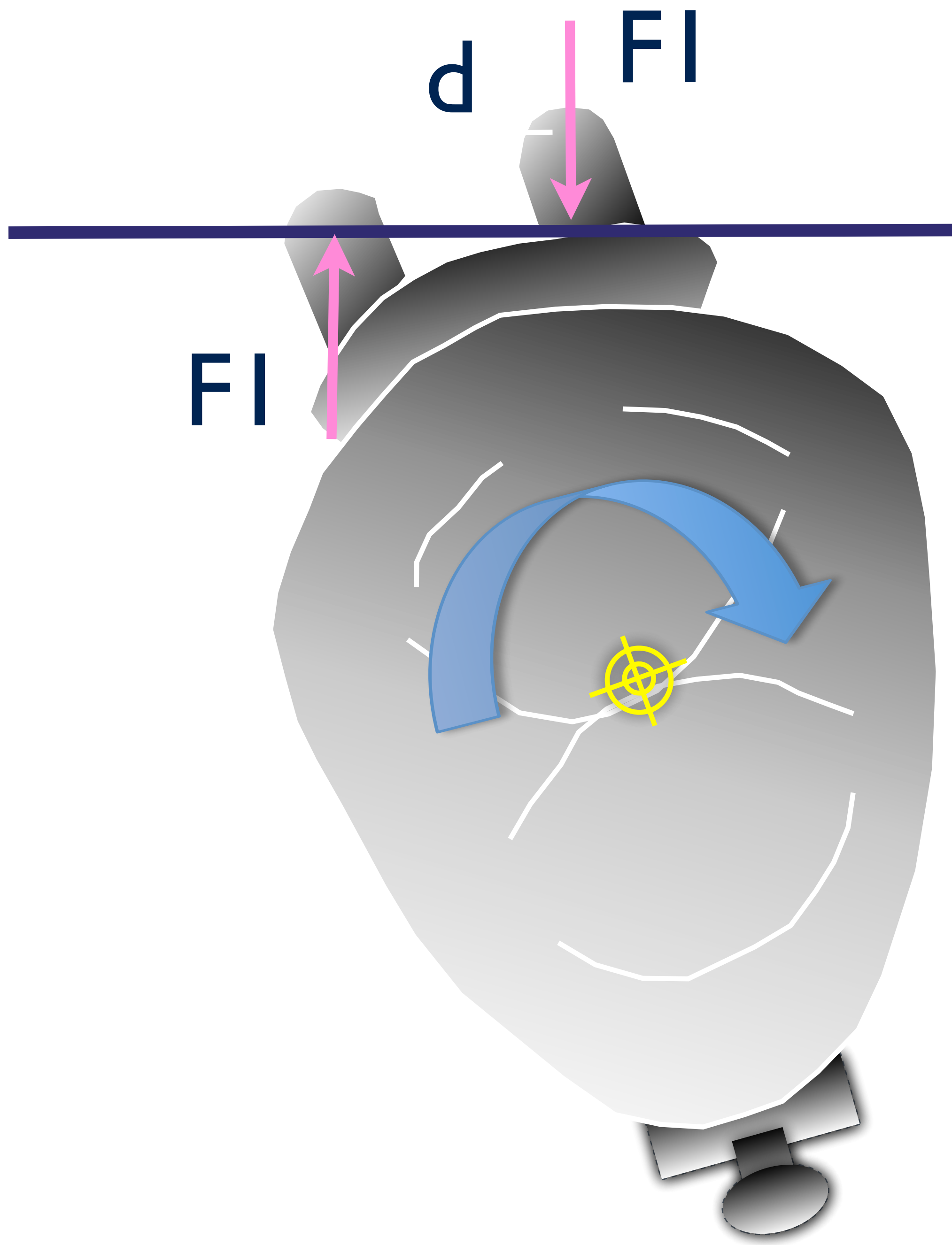


C.rot = CR

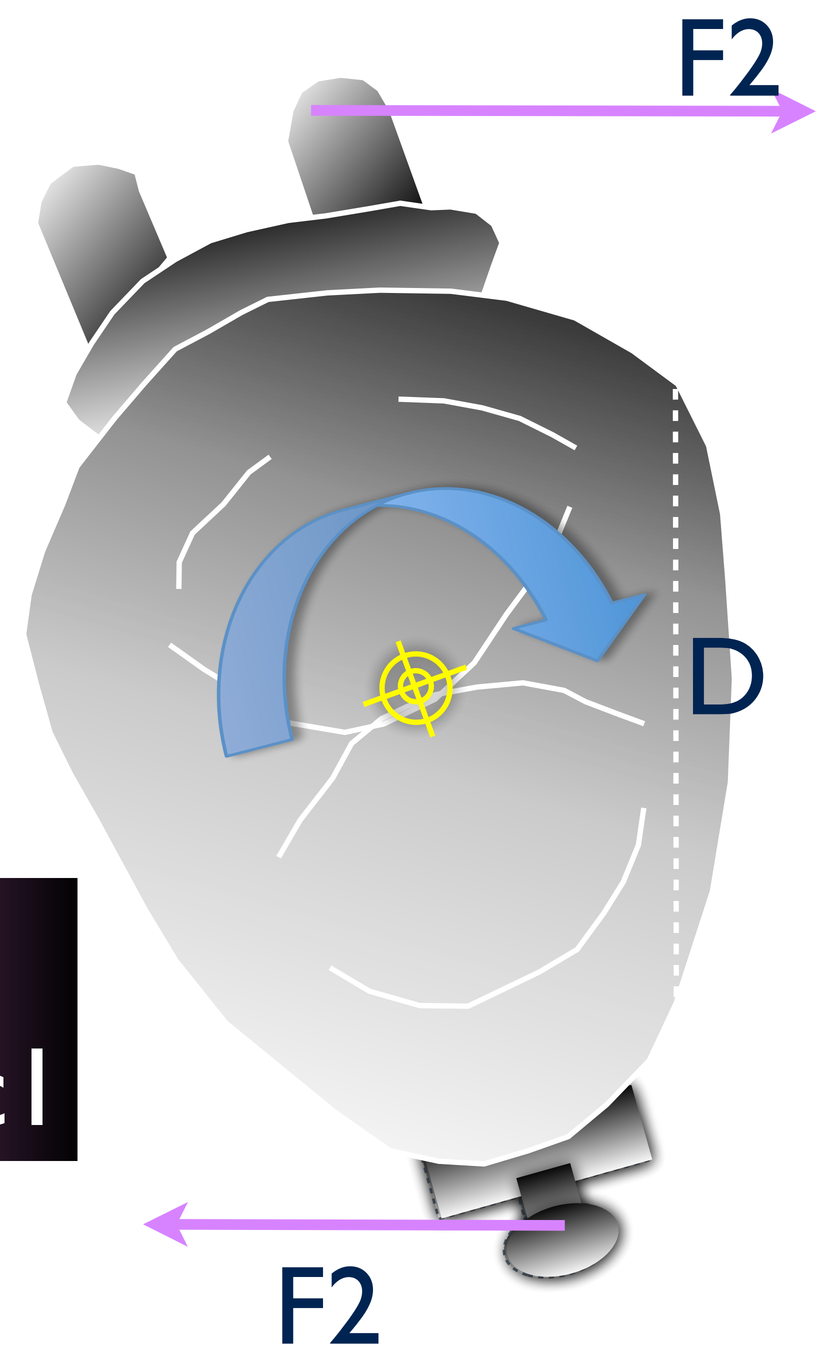


C.rot = incisal edge

$M.c1 = F1 \times d$



$M.c2 = F2 \times D$



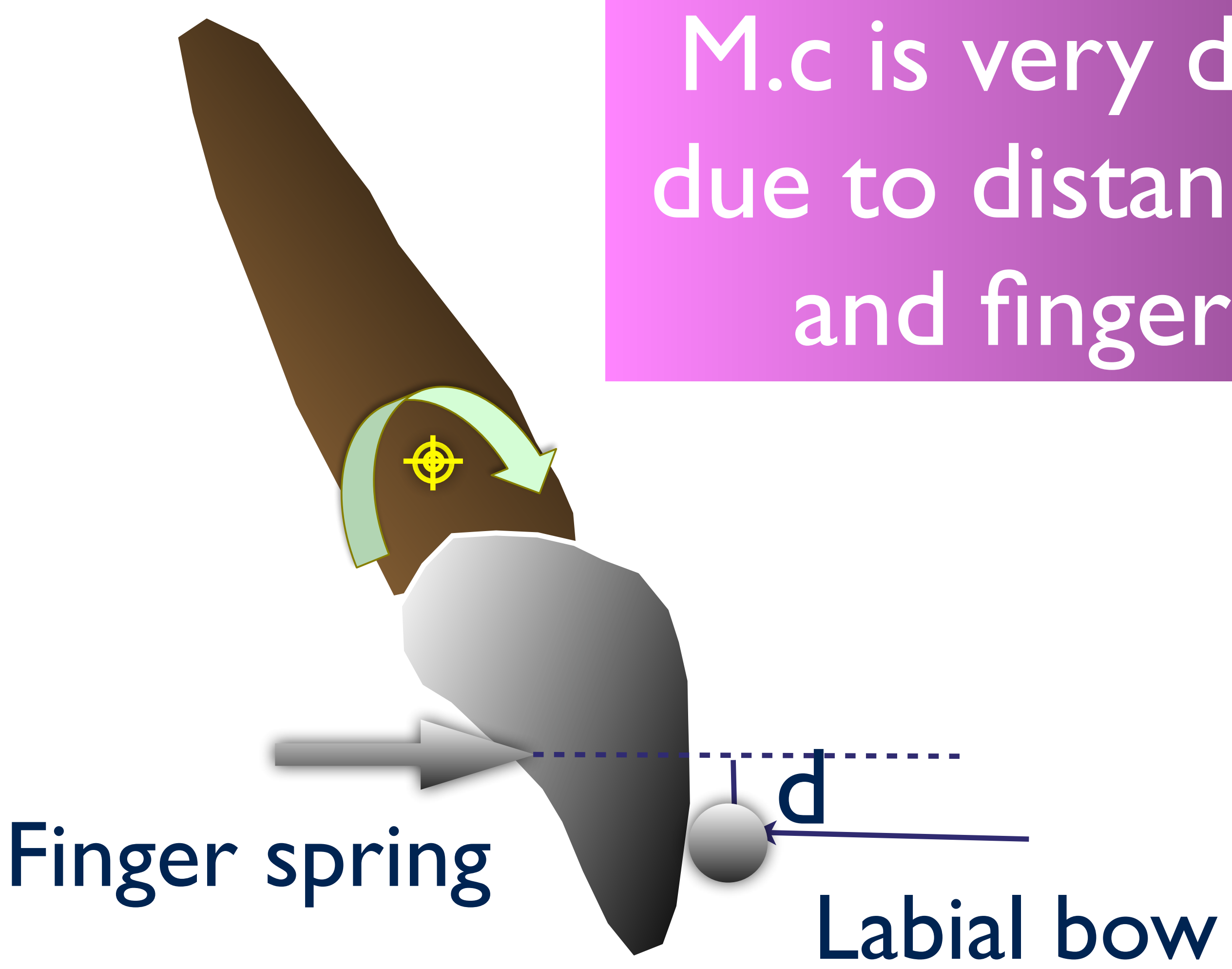
F1=F2

M.c2 > M.c1

Less force (pain) but more effective

Moment of couple in Removable Appliances

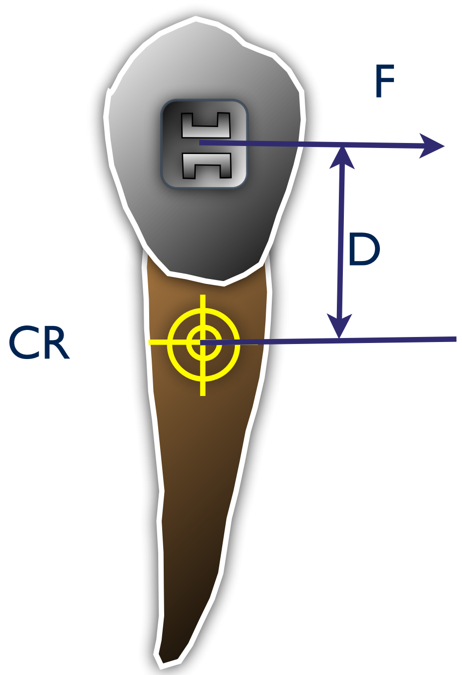
M.c is very difficult to initiate in RA. due to distance between labial spring and finger spring is very short.



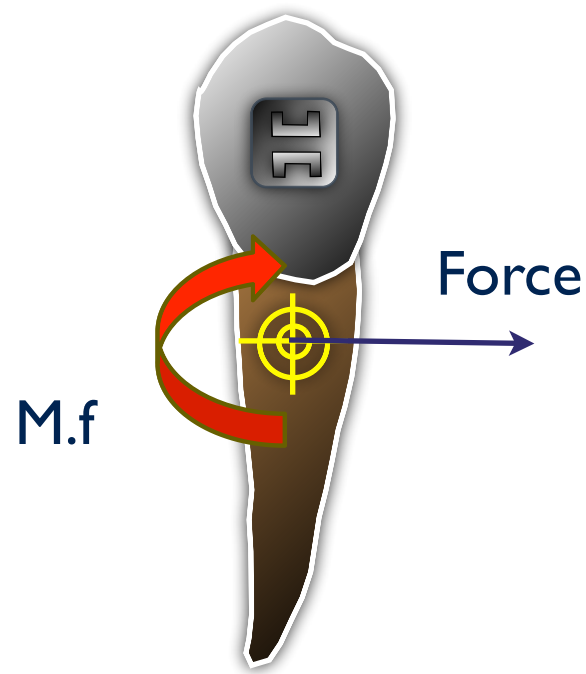
Force System and Center of Rotation

The method for predicting the type of tooth movement(Center of Rotation)

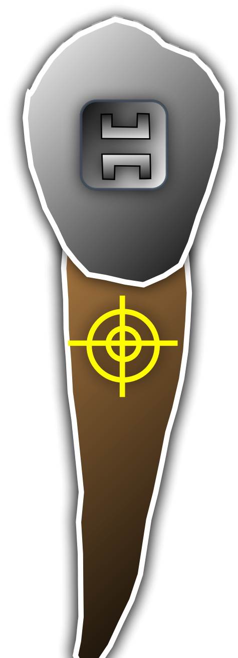
Resultant orthodontic single force (not through CR) → Single force at CR(Translation) + M.c (Pure Rotation) → Type of tooth MM (Location of C.rot)



M.f = FD

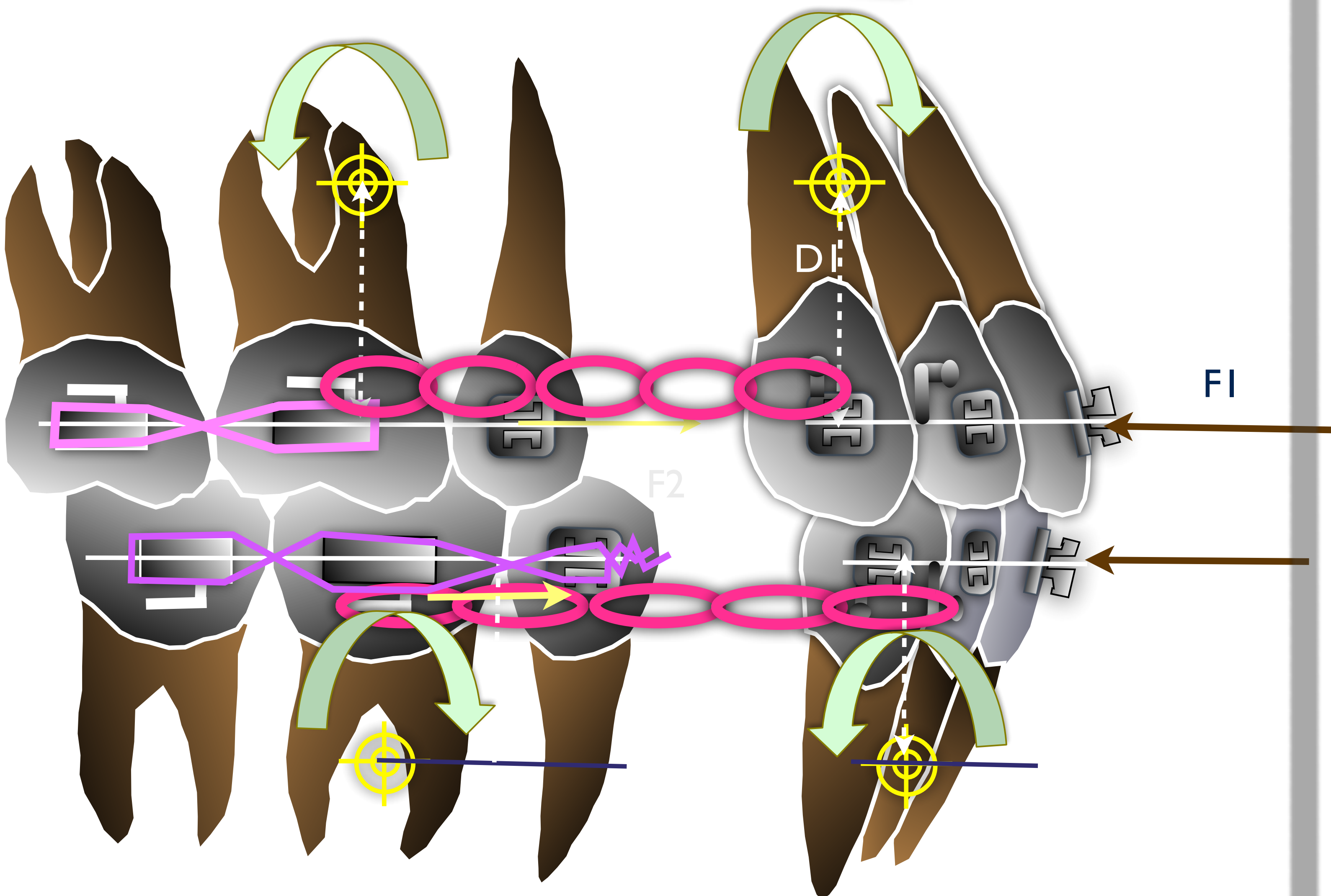


Force System



Type of tooth MM.

Force System & clinical application



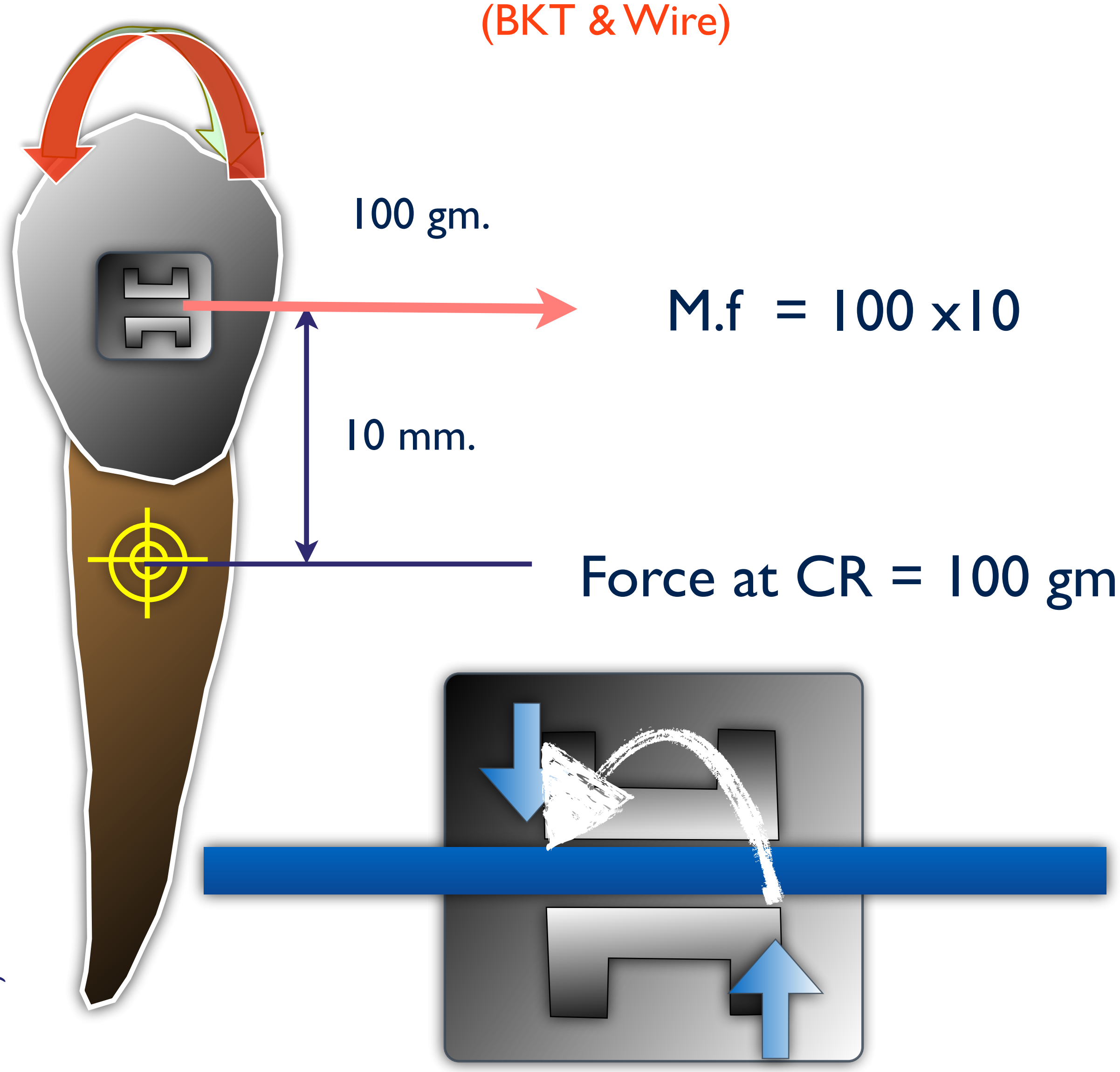
-Overbite increased
-1/1 retrocination
-Mesial tipping of buccal segment (Anchorage loss)
-Bite opening around #3 - #5
- Usually this situation occurs in space closure by full strap power chain (จัดฟันแบบTurbo)

Force System & Equivalent Force System

(Action & Reaction)

-The method for predicting the type of tooth movement(Center of Rotation).
-Determining equivalent FS to control tooth MM

Equivalent force system
(BKT & Wire)



Force System (Action)

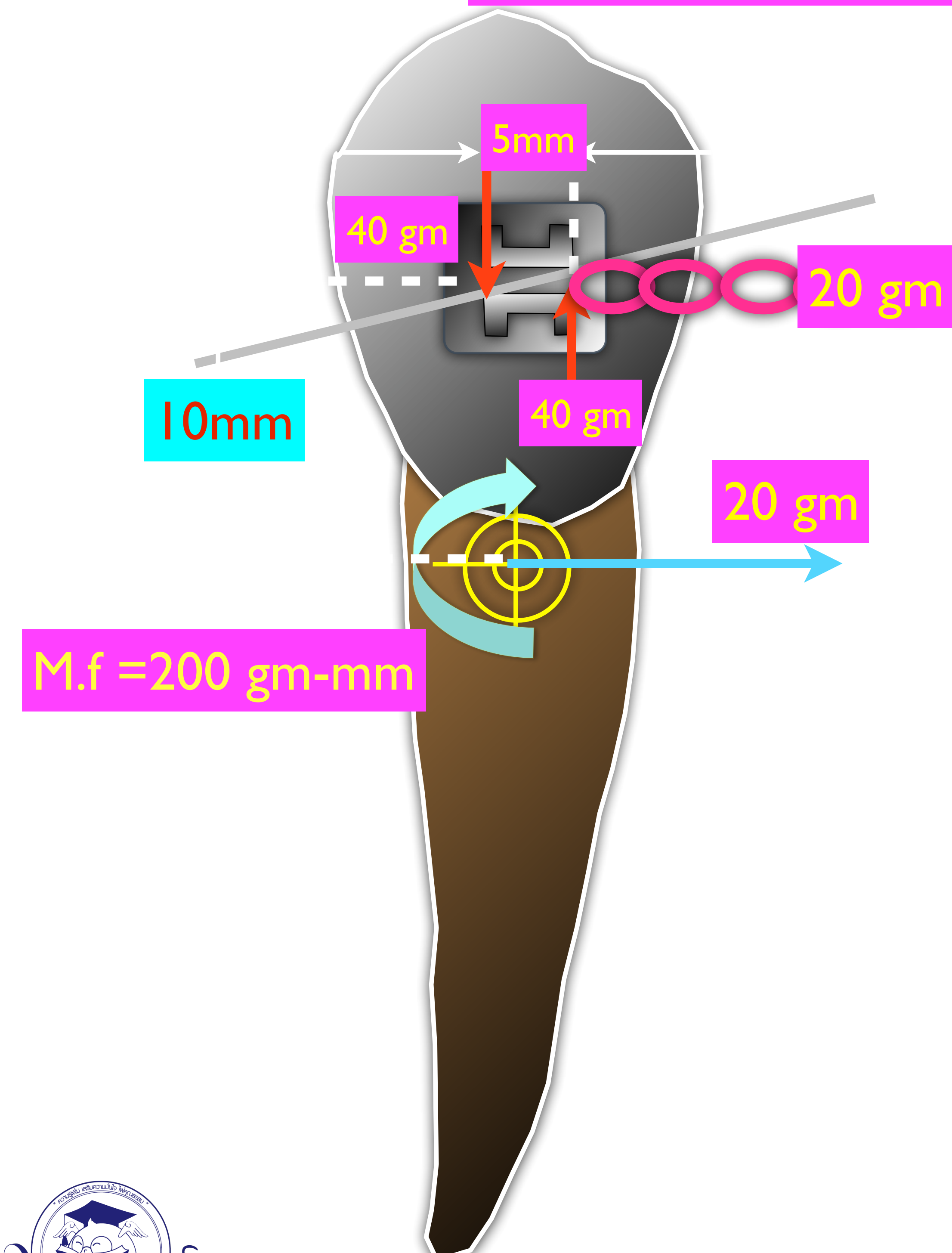
M.f = 100 x10
= 1000 gm-mm
= Clockwise crown tipping
Force at CR = 100 gm
= Translation

Equivalent force system (Reaction)

Counter clockwise moment
-M.c at CR
Mc> 1000gm-mm = Root MM
Mc< 1000gm-mm = Crown tipping
Mc= 1000gm-mm = Translation

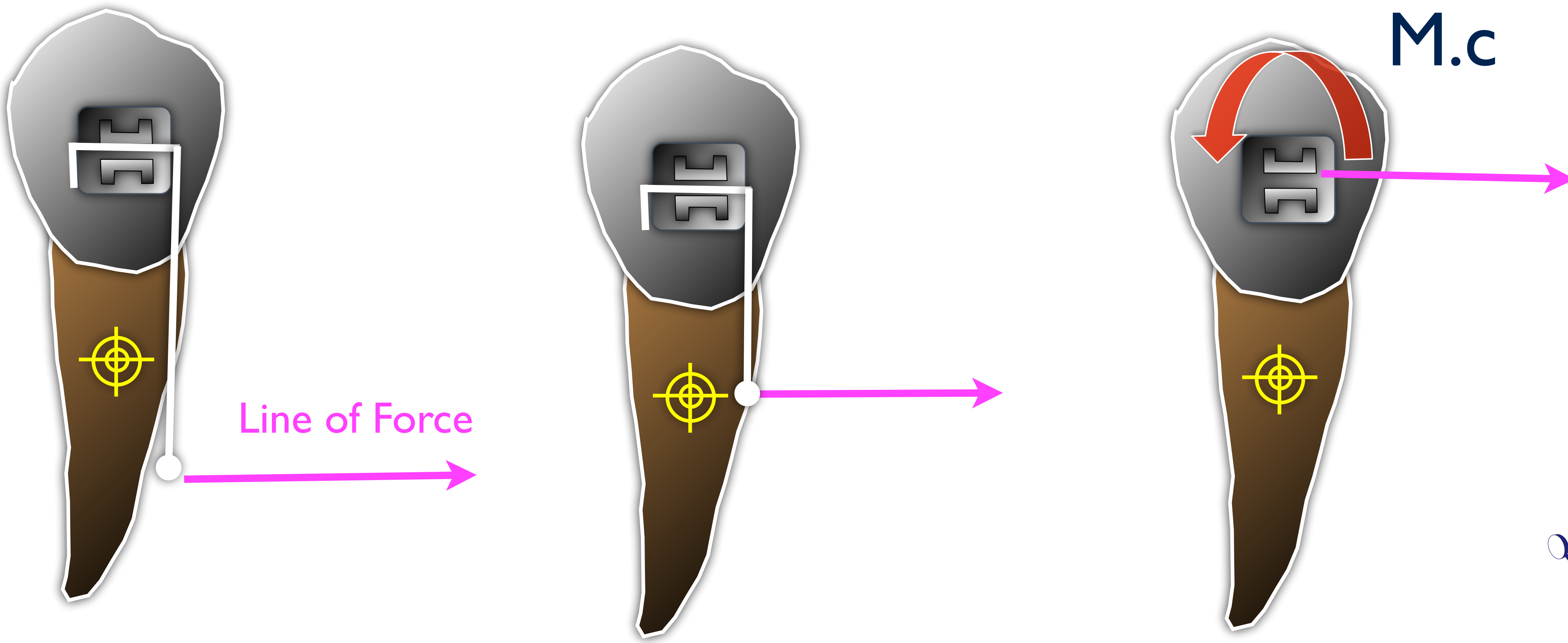
The amount of equivalent force

can determine the type of tooth MM.



	Moment	Force	Result
Force system	20 x 10 =200 gm-mm Clockwise	at CR = 20 gm.	Crown tipping
Equivalent Force	40 x 5 =200 Anti-clockwise	None (couple)	Translation by 20 gm. at CR
	M.c> equi force (Gable-bend,)		Root MM. or torque
	M.c< equi force (V-bend)		Crown tipping

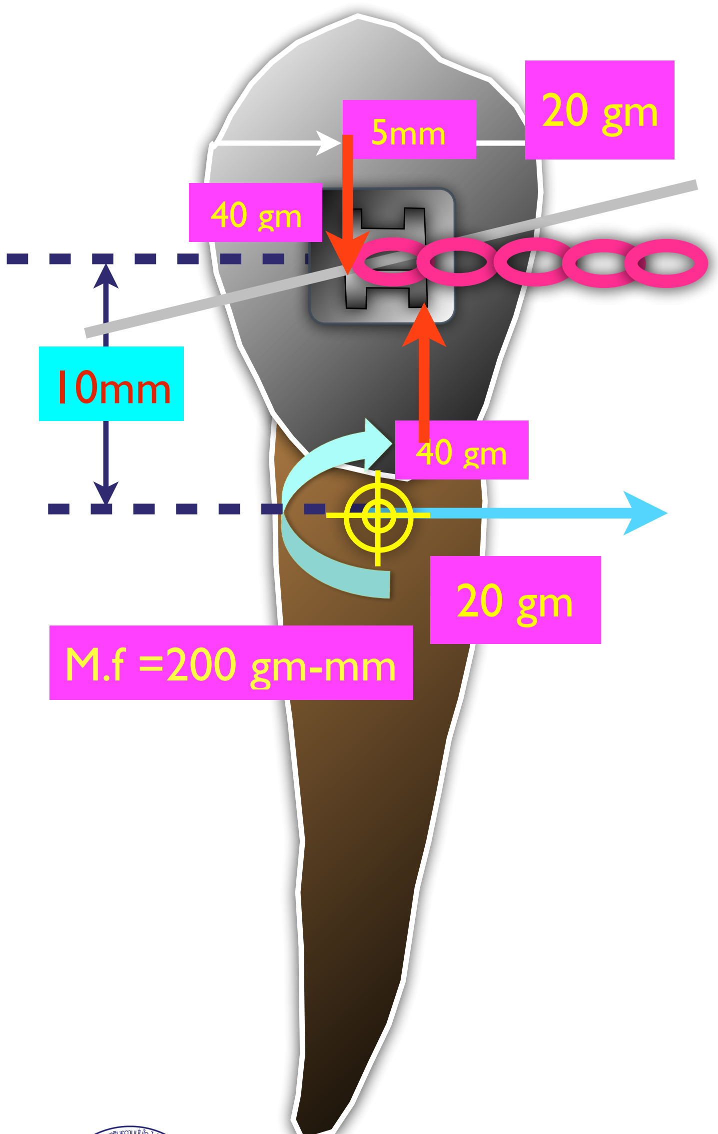
How to control the orthodontic force to get a desirable tooth movement ?



Controlling the line of force relative to CR according to the type of tooth MM needed

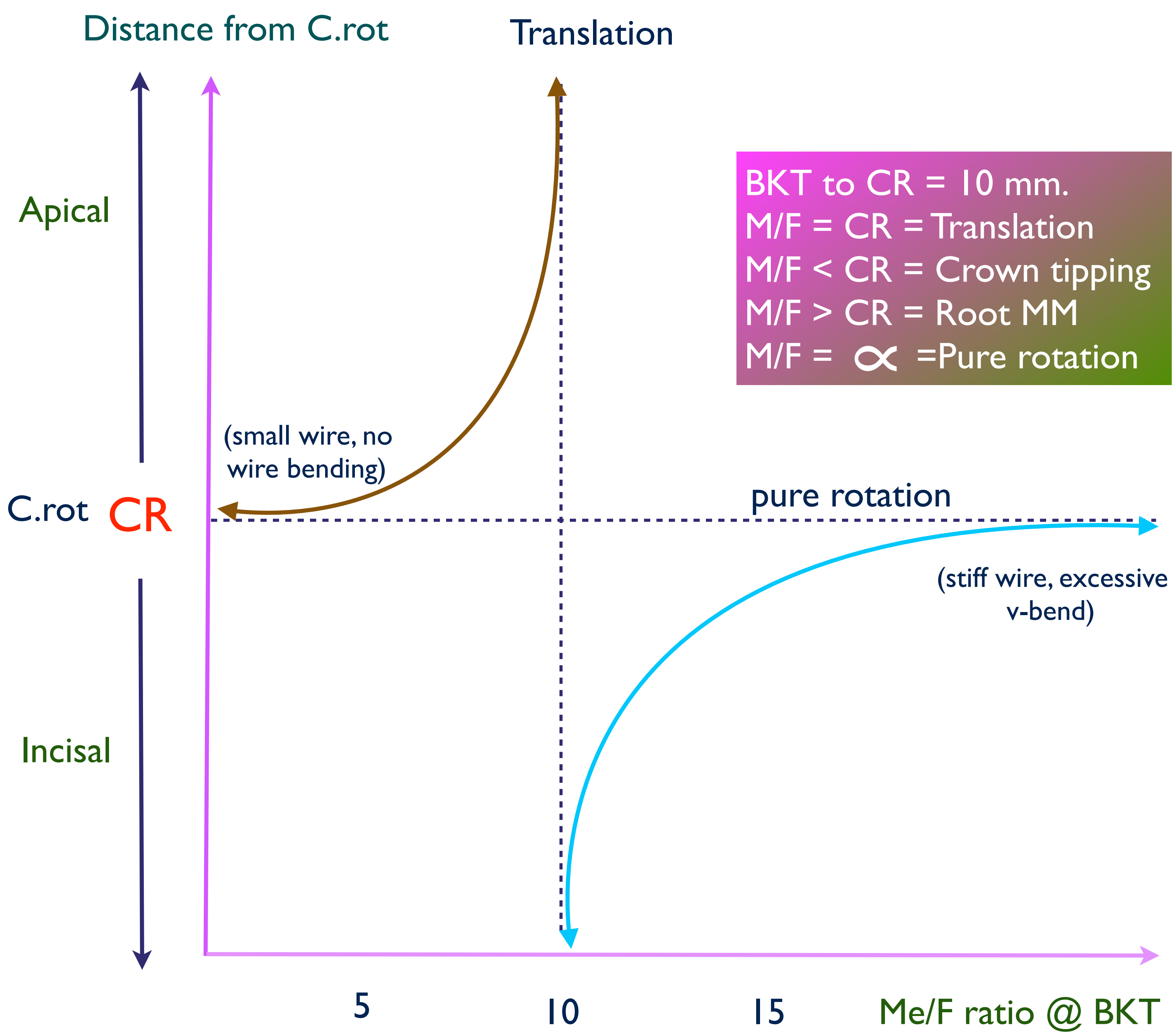
Regulating amount of M.c in the bracket produced relative to M.f when the force applied at bracket

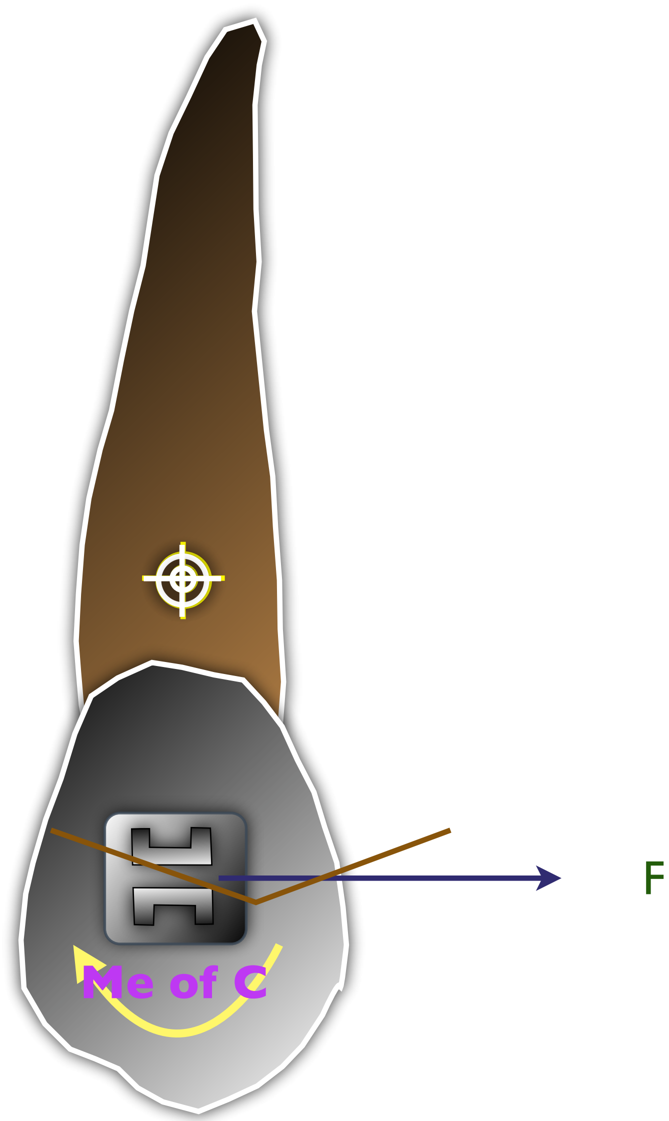
FS & EFS & M/F ratio & Type of Tooth MM.



	Couple force (MOC)	Moment @ CR	Force	M.e/F Ratio	Relative to CR	Result
Force system	---	20 x 10 =200 gm-mm Clockwise	at CR = 20 gm.	---	LOF to CR =10 mm.	Crown Tipping
Equivalent FS	40 gm	40 x 5 =200 Anti-clockwise	None (couple)	200/20=10	**M/F = CR(10mm)**	**Translation**
	< 40 gm. (small wire, no wire bending)	F.c x 5 < 200		<200/20<10	**M/F < CR**	**Crown Tipping**
	>40 gm. (stiff wire, v-bending)	F.c x 5 > 200		>200/20>10	**M/F > CR**	**Root MM**
No force at BKT	Any	Any	F=0 gm.	∝	∝	Pure Rotation

M/F ratio and C.rot





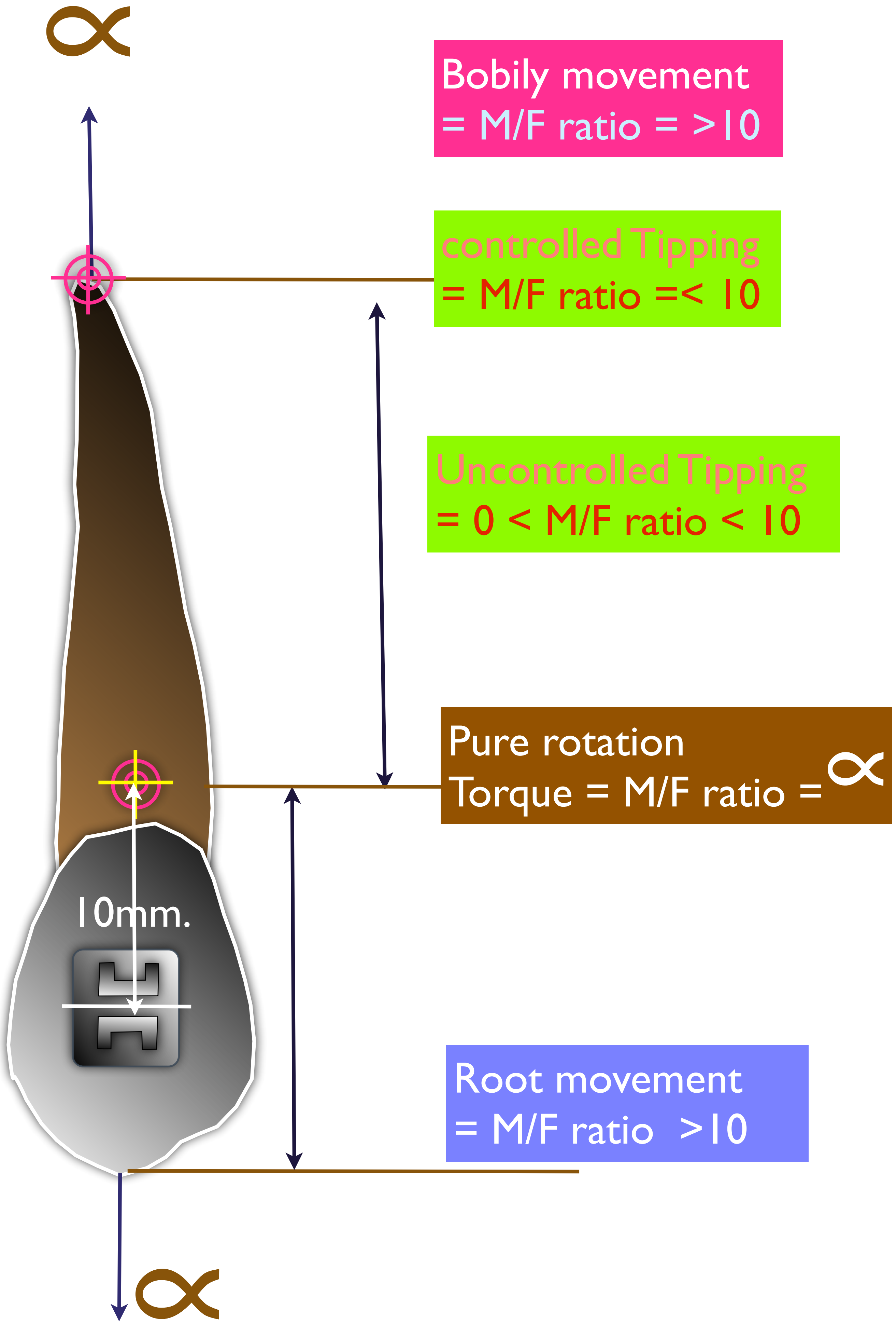
M_c/F ratio & C.rot for max incisor

CR to Bracket = 10 mm.

Mf =F x Distance CR to BKT
M.f/F = Distance CR to BKT

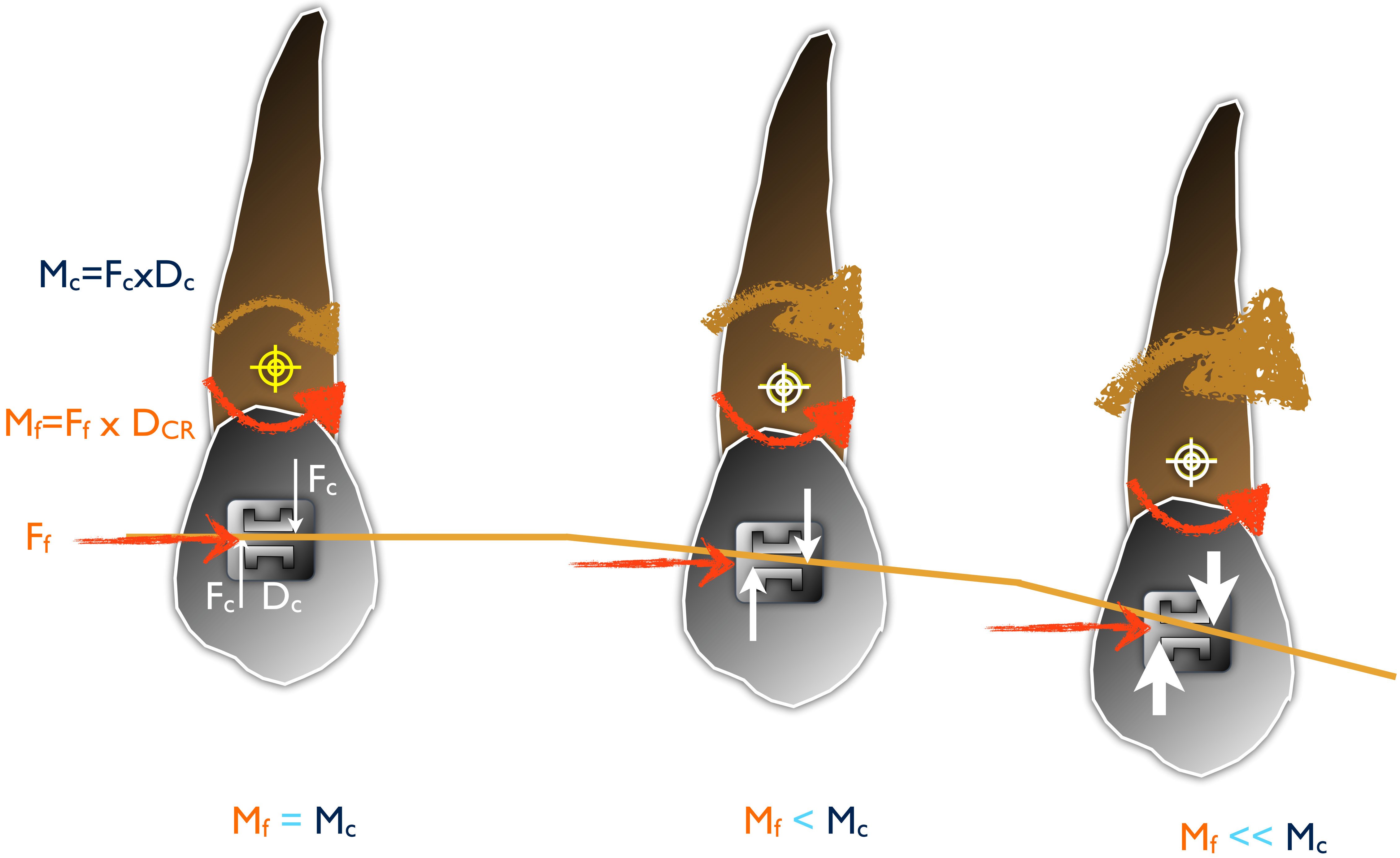
Type of tooth MM	M/F ratio	C.rot
Translatiom	10	Infinity
Controlled tipping	5	Apex
Uncontrolled tipping	0	CR - Apex
Root MM	12	CR - incisal edge
Pure rotation	∝ (No Force)	CR

Center of Rotation & Moment to Force Ratio



M/F ratio is used to describe type of tooth movement

Clinical implicaton



Static Equilibrium

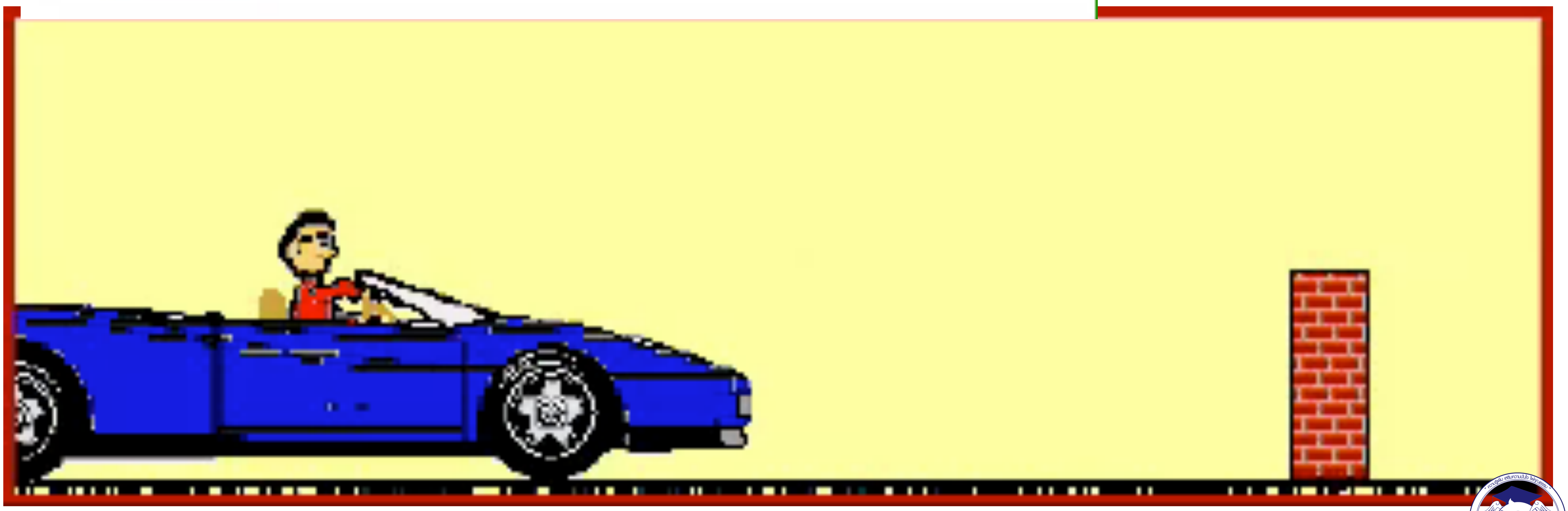
Newton's laws

Law of inertia : Every body continues in its state of rest or uniform motion in a straight line unless it is compelled to change by the force impressed on it (seat belt) (Dynamic Equilibrium)

Law of acceleration : the change in motion is proportional to the impressed motive force and is made in the direction of the straight line in which the force is impressed (F=ma)

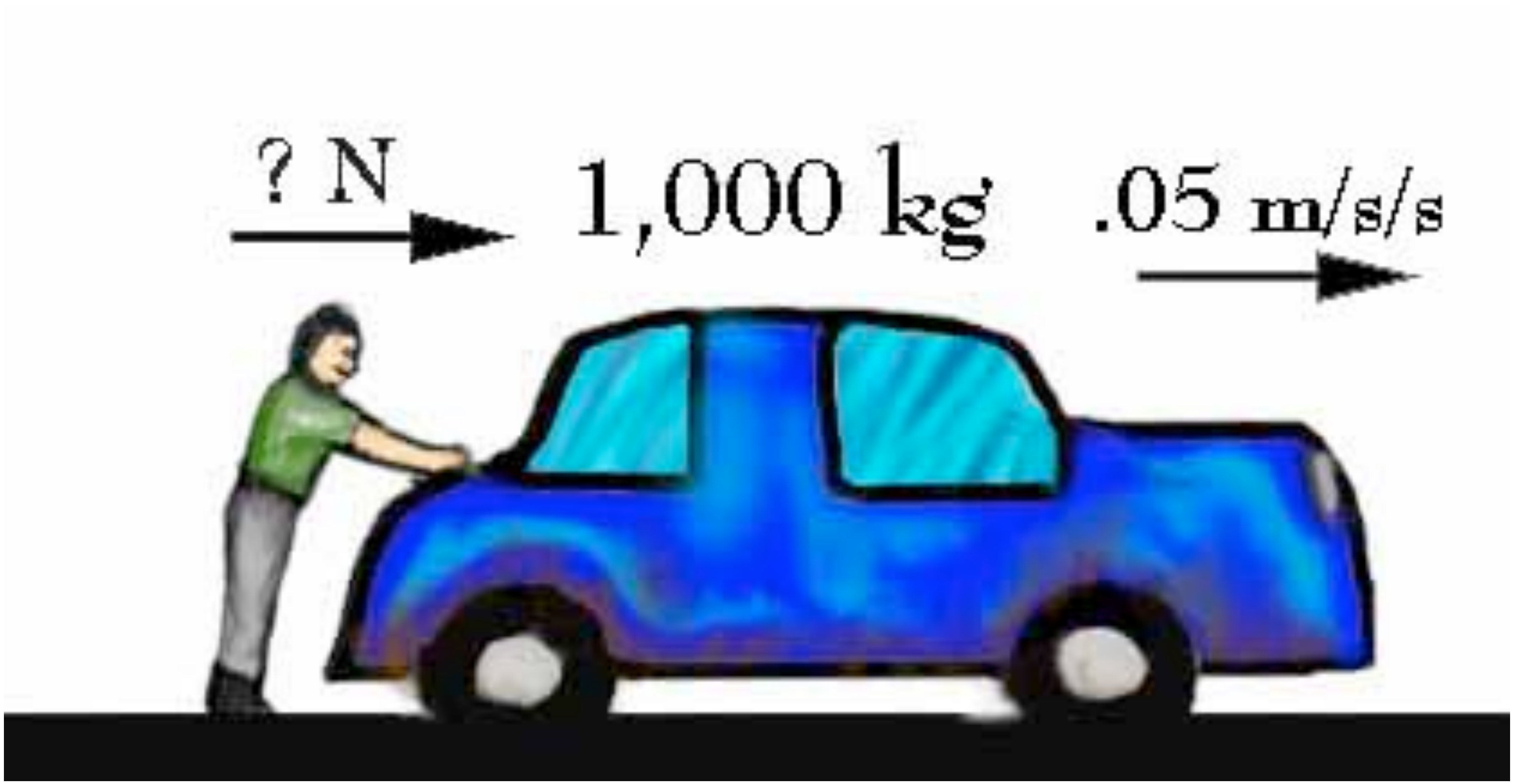
Law of action and reaction : To every action there is always an opposing and equal reaction (Rocket)(Static Equilibrium)

Law of inertia



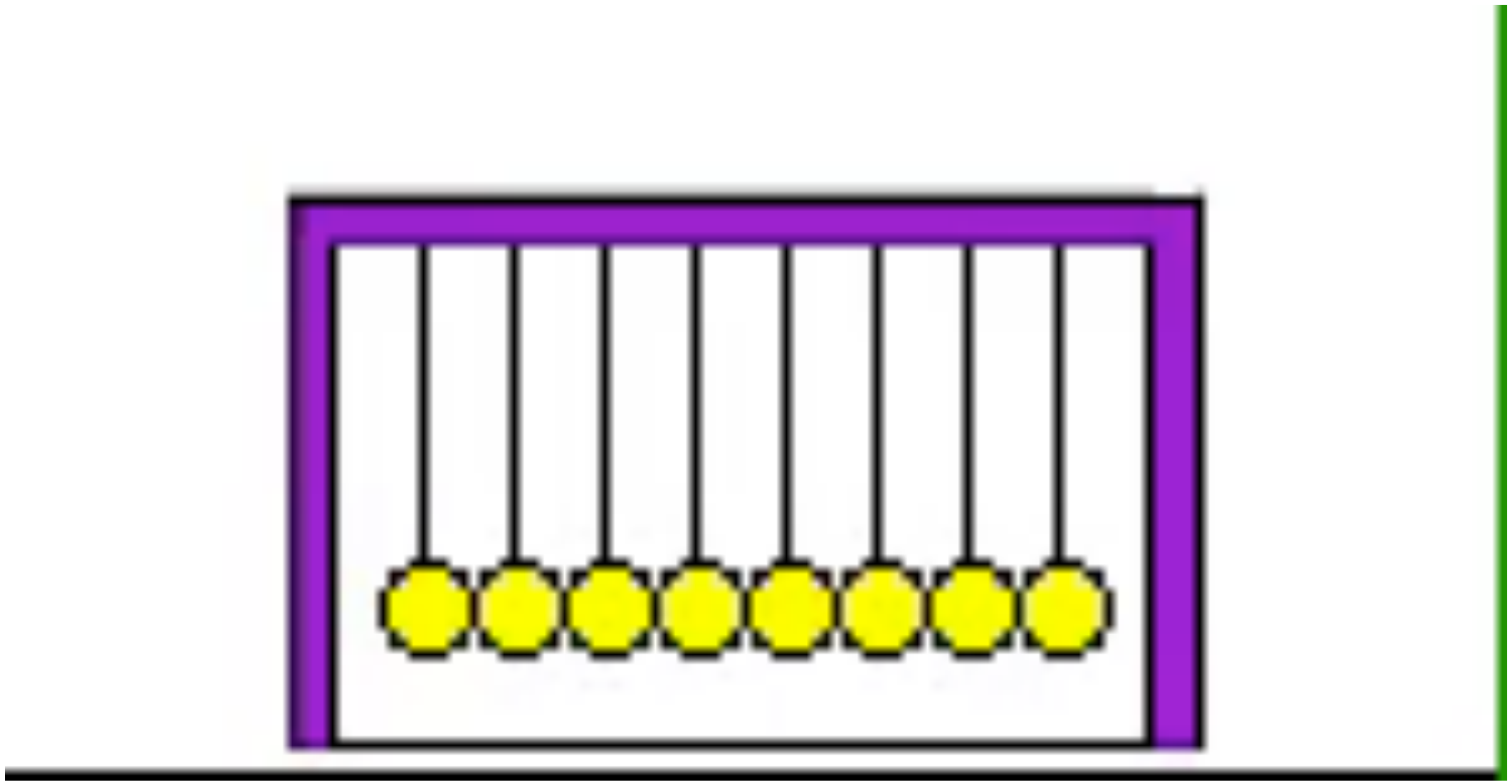
Law of acceleration

Acceleration is produced when a force acts on a mass. The greater the mass (of the object being accelerated) the greater the amount of force needed (to accelerate the object).



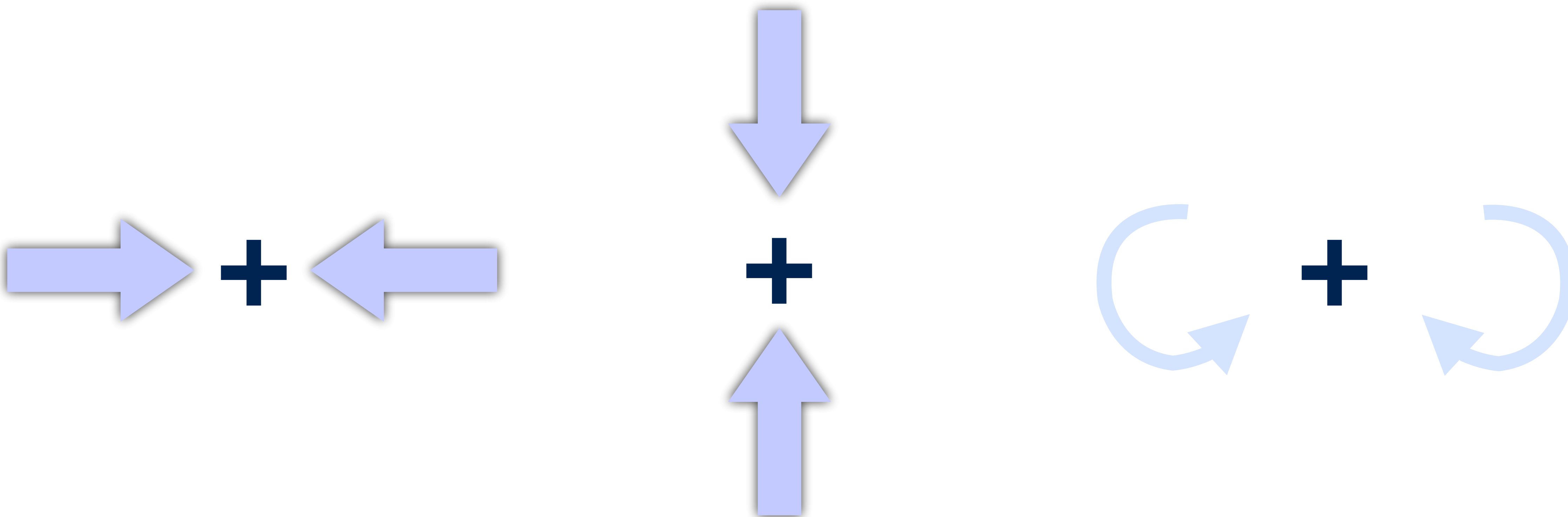
Law of action and reaction

For every action there is an equal and opposite re-action.



Static Equilibrium

- STATIC EQUILIBRIUM IMPLIES –AT ANY POINT WITHIN A BODY, THE SUM OF FORCES AND MOMENTS ACTING ON A BODY IS ZERO.
- THE ANALYSIS OF EQUILIBRIUM AS APPLIED TO ORTHODONTICS CAN BE STATED AS



Static Equilibrium

Is used to analyses the whole of every force system to predict tooth movement in the equilibrium

can be stated in equation form

Horizontal forces =Fx=0
Vertical forces =Fy=0
Transverse forces =Fz=0

Moments (X axis) =Mx=0
Moments (Y axis) =My=0
Moments (Z axis) =Mz=0

Static Equilibrium Situation

Many appliances and bends placed in clinical situations

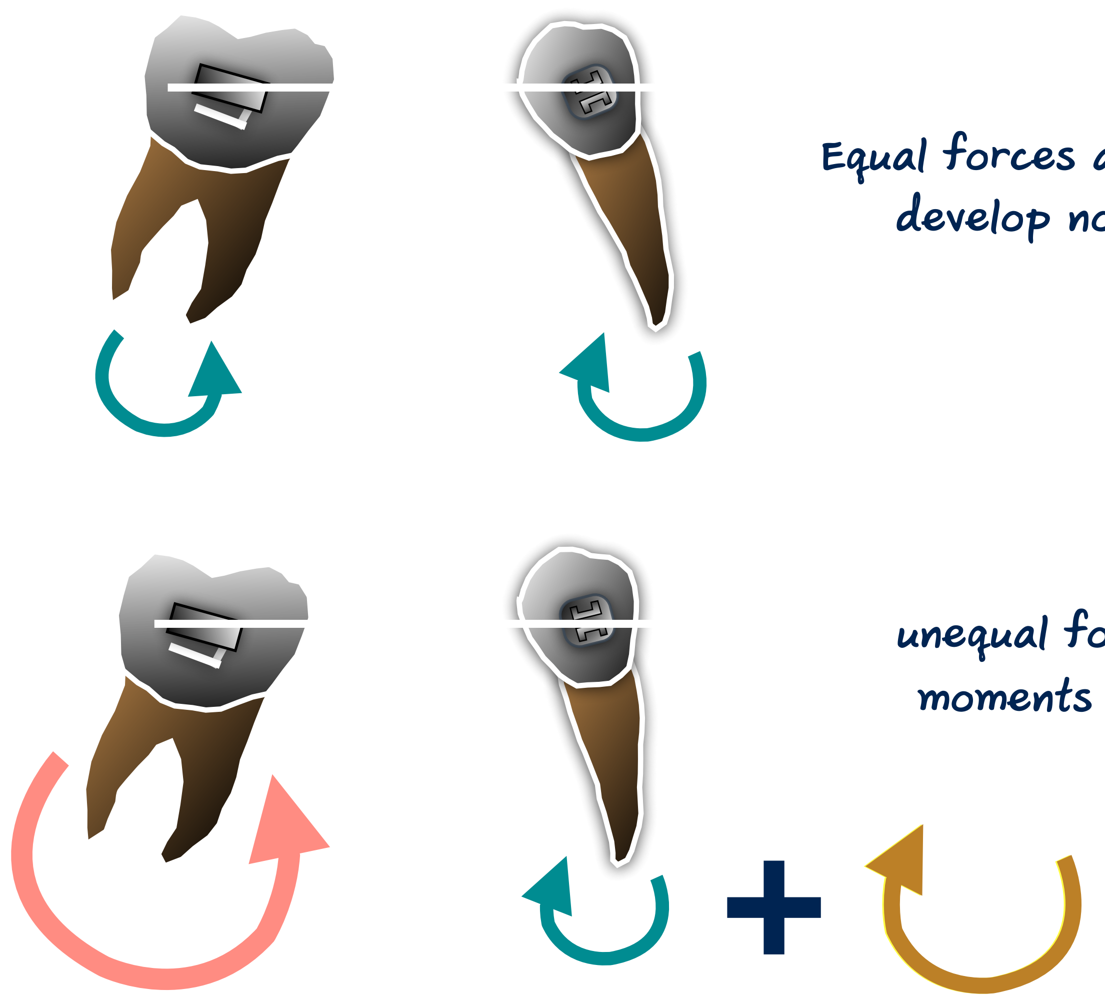
Many situations –unequal forces and moments develop.

“Additional forces”-develop to obtain equilibrium

Determination of complete system in equilibrium-side effects.

The forces and moments that determine a appliances equilibrium –must exist.

Clinical situation of Static Equilibrium



Equal forces and moments develop no moment

Moment acting around any point must = 0

unequal forces and moments develop

Forces produced to maintain static equilibrium

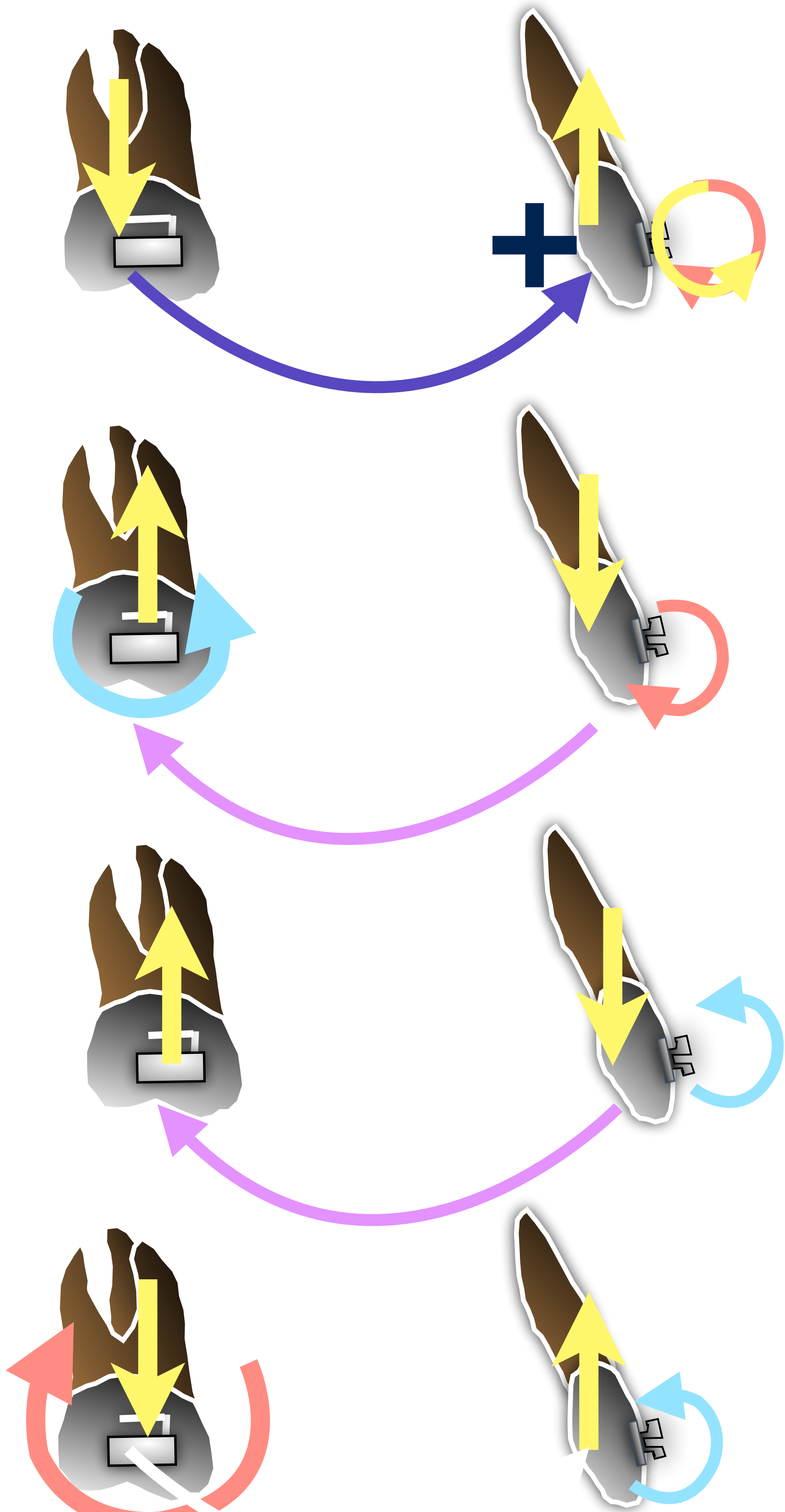
Additional forces

Extrusion Intrusion

side effects

Magnitude of forces exactly necessary to produce a counter rotation.

Pre-torque 20



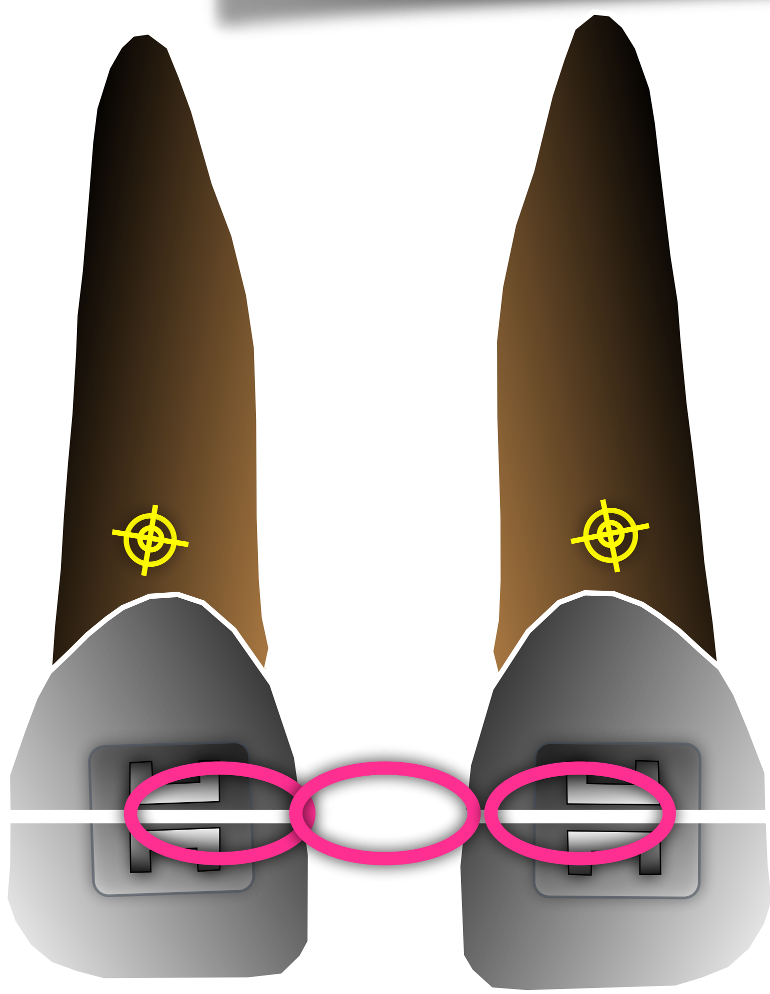
MOMENT : LABIAL ROOT TORQUE OF 1/–
SIDE EFFECT
–INTRUSION OF 1/–
–EXTRUSION OF 6/–

MOMENT : LABIAL ROOT TORQUE OF 1/– &
MESIAL TIPPING OF 6/–
SIDE EFFECT
–INTRUSION OF 6/–
–EXTRUSION OF 1/–

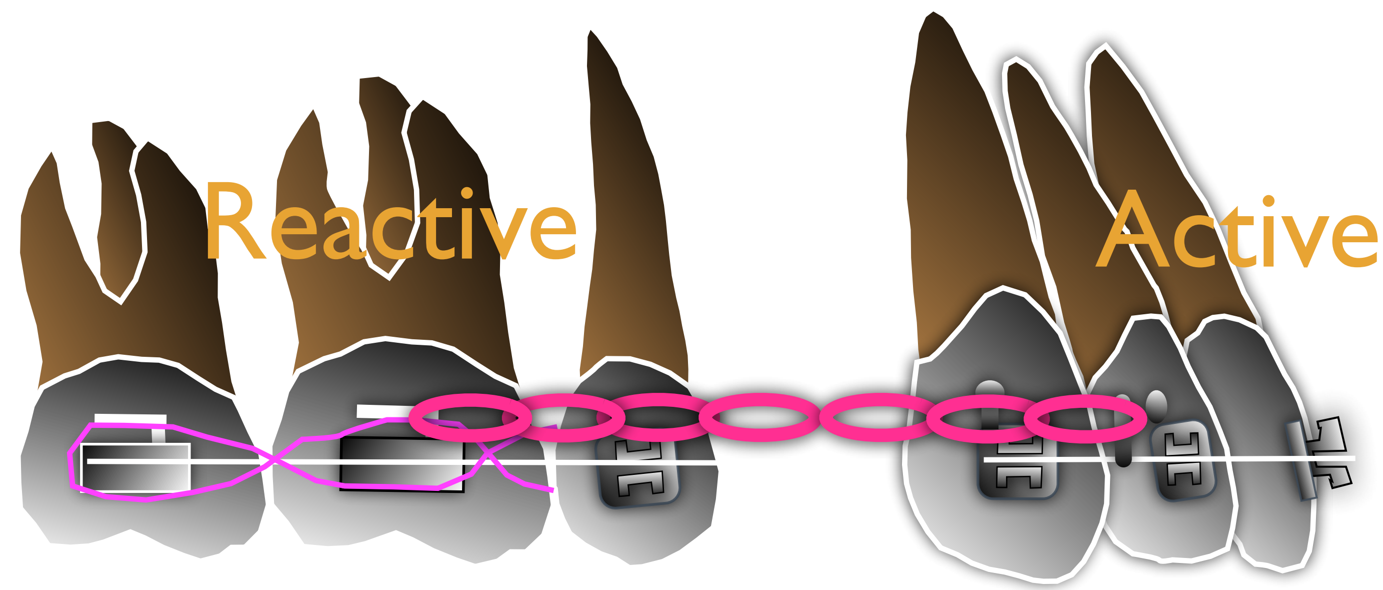
MOMENT : PALATAL ROOT TORQUE OF 1/–
SIDE EFFECT
–INTRUSION OF 6/–
–EXTRUSION OF 1/–

MOMENT : PALATAL ROOT TORQUE OF 1/– &
DISTAL TIPPING OF 6/–
SIDE EFFECT
–INTRUSION OF 1/–
–EXTRUSION OF 6/–

Clinical situation of Active & Reactive

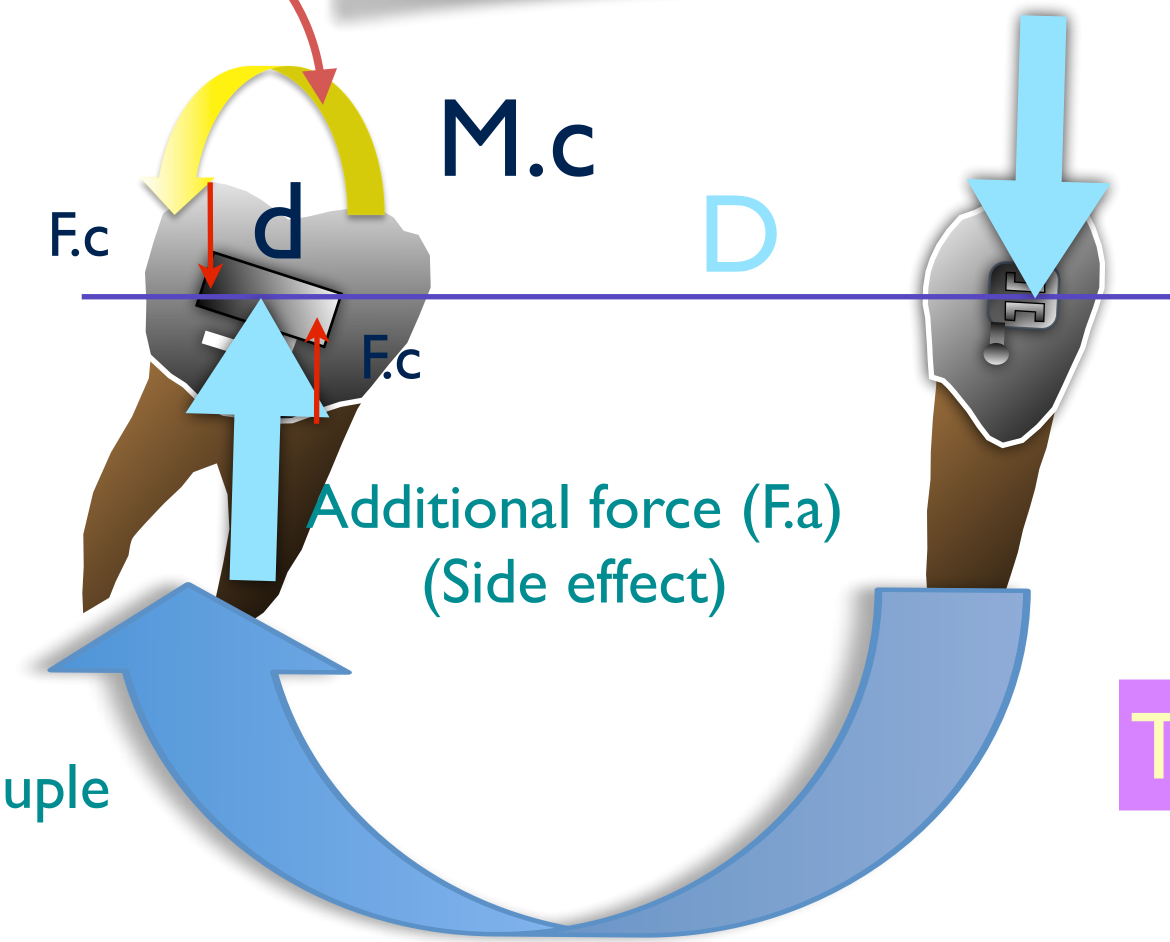


Active/Reactive



Active Part :
serves as tooth movement part
Reactive Part :
serves as anchorage
Combination Part :
serves as both movement and anchorage

Static Equilibrium



Tooth movement prediction

Canine:

Intrusion (Side effect)

Molar:

Distal tipping

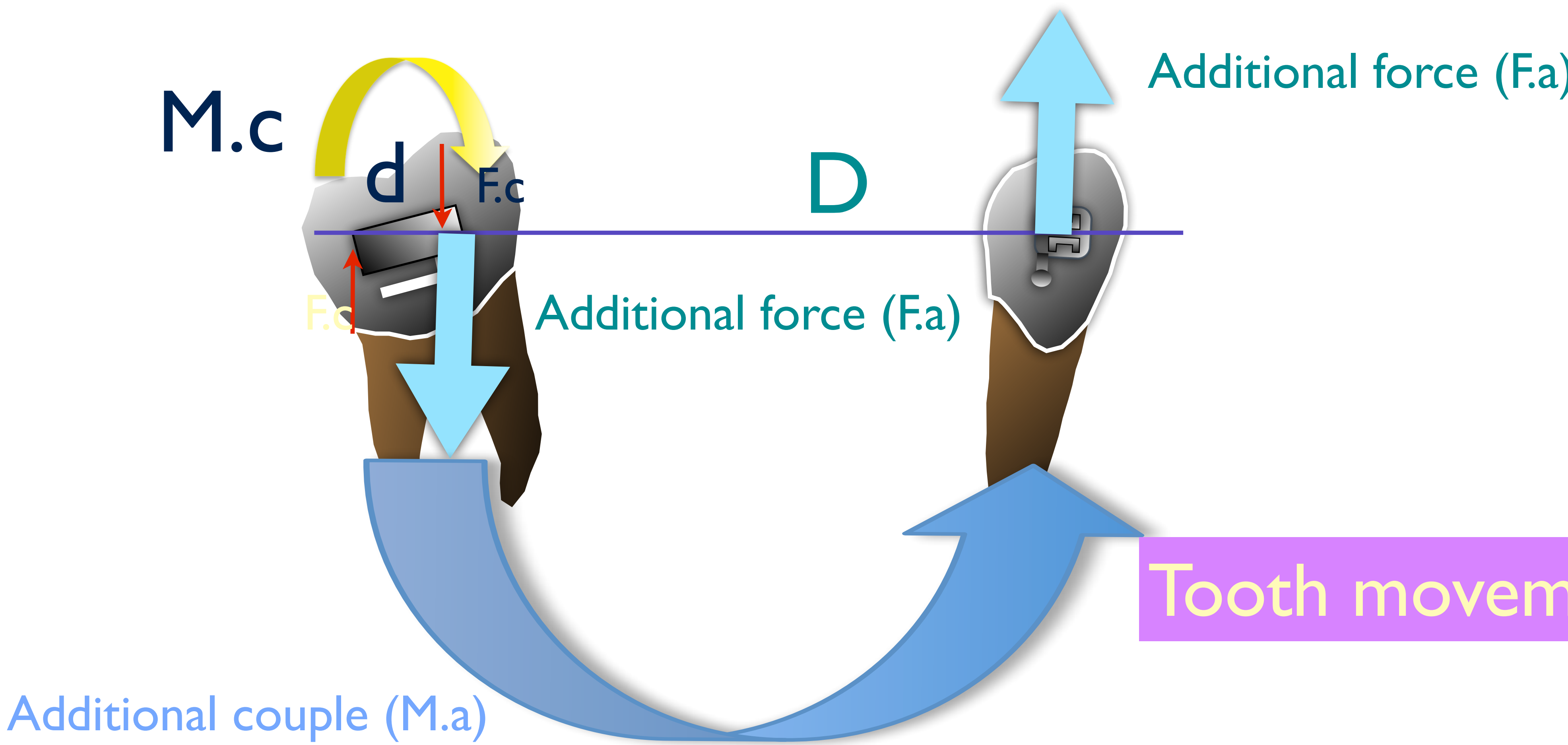
Extrusion (Side effect)

Static equilibrium

$M.a = M.c$

$F.a \times D = F.c \times d$

$F.a / F.c = d / D$



Tooth movement prediction

Static equilibrium

$M.a = M.c$

$F.a \times D = F.c \times d$

$F.a / F.c = d / D$

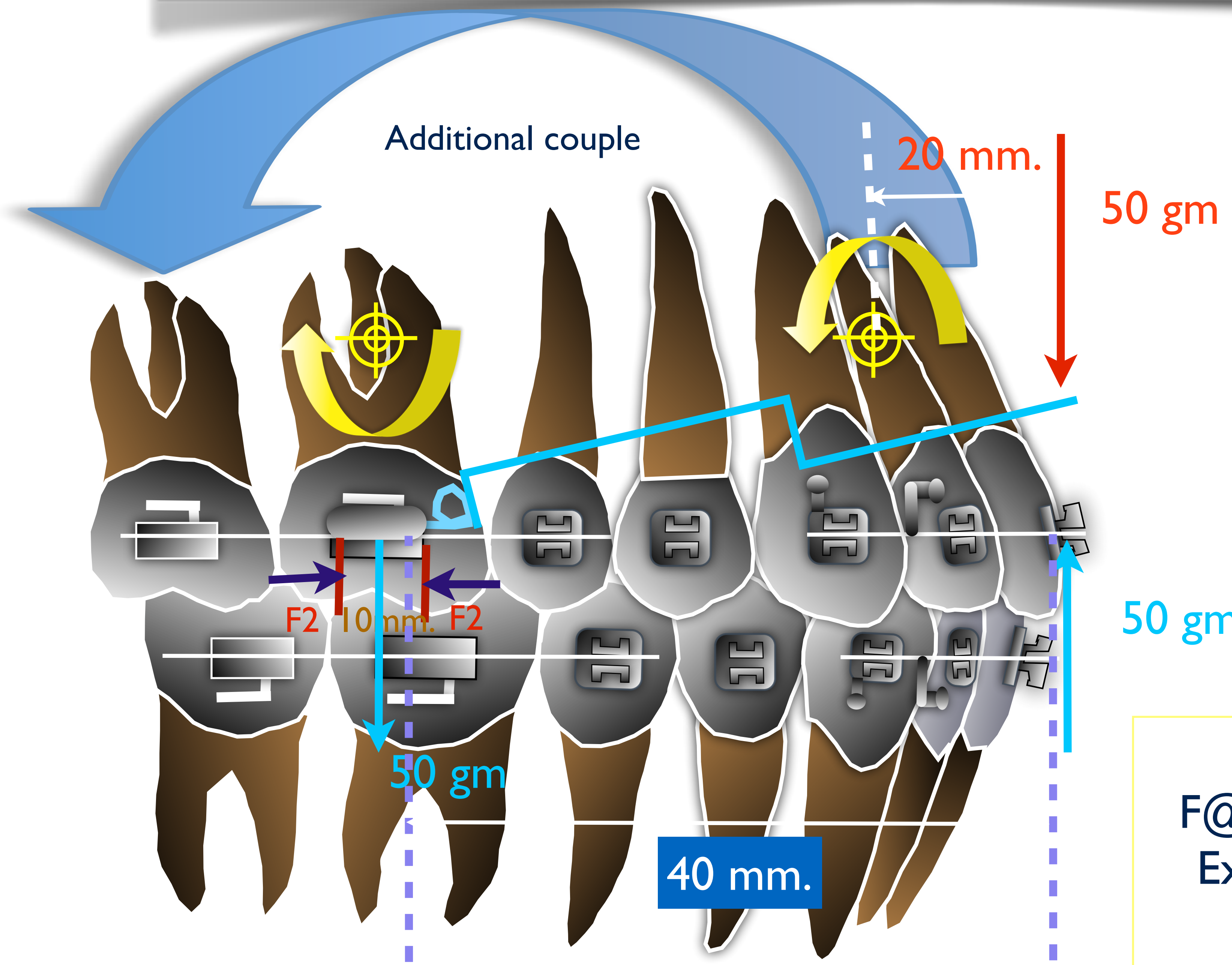
Canine:

- Extrusion

Molar:

- Mesial tipping
- Intrusion

Static Equilibrium & Orthodontics



Force System1

M.f1 = 50 x 20 gm-mm
=1000 gm-mm
F@CR = 50 gm.(intrusion)

Force system2

M.c2 = F2 x 10mm.
= 10F2 gm-mm

Additional couple

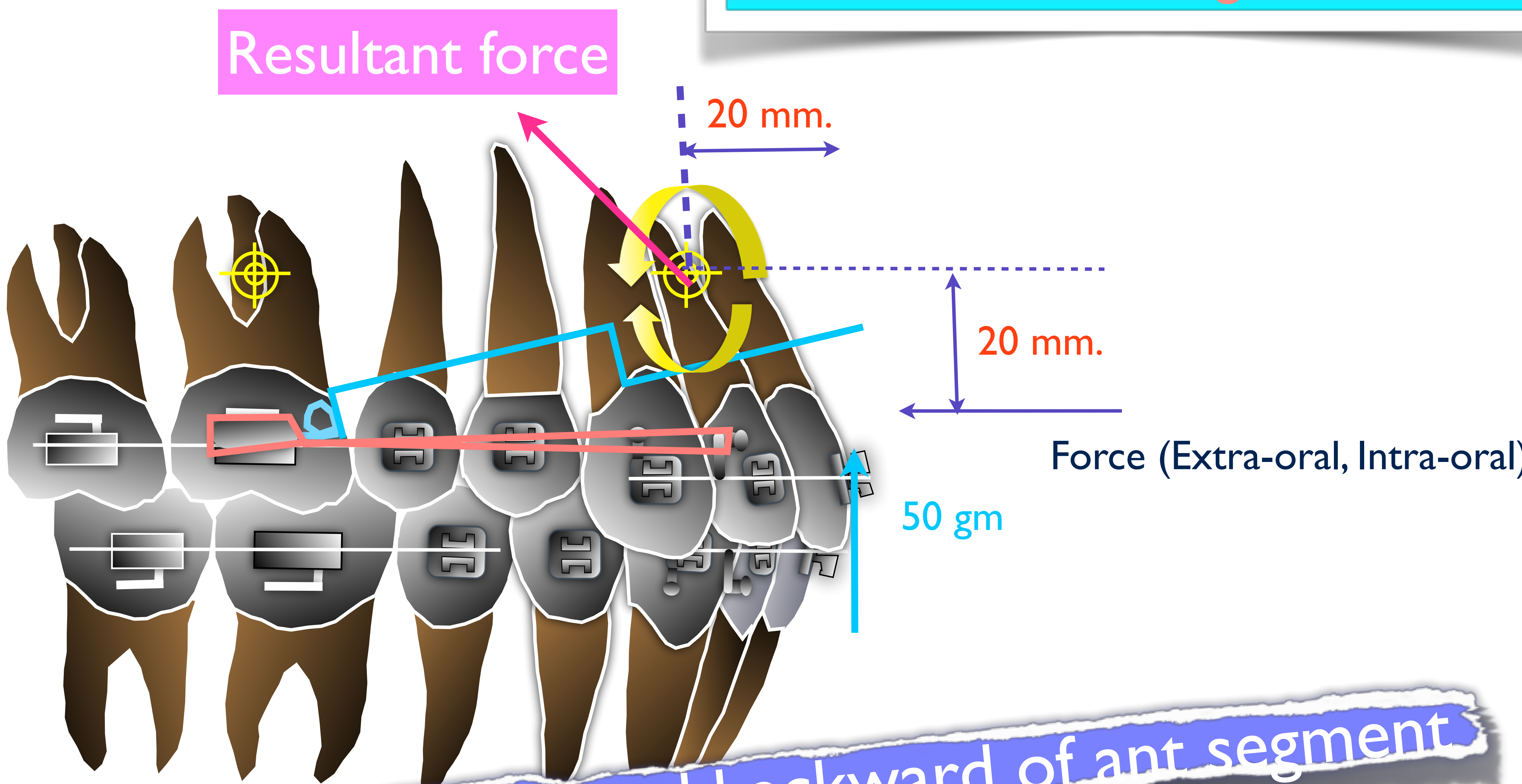
F@CR(ant Intrusion force) = 50 gm.
Extrusion force @ Molar = 50 gm.

M.e (ad) = 50 x 40
=2000 gm-mm

Static Equilibrium

M.f1+M.e(ad) = M.c2
1000+2000 = 10F2
F2 = 3000/10 = 300 gm.
M.c2 = 10x300 = 3000 gm-mm

Force system analysis at anterior segment



Translation upward and backward of ant segment