

# Chapter I

## Basic Biomechanics

### CONTENTS

Biomechanics : Definition, what it means in our context.

Force: its importance in our practice, definition, depiction, units of measurements, active elements.

Two parallel forces having same sense or opposite sense, a force couple, importance of non-co-linearity.

Two non-parallel forces, parallelogram method for deriving their resultant, Law of 'transmissibility of forces', 'sliding' vector; application of the law when arrows do not meet, resolving a single force into two components, resultant of more than two forces.

Center of resistance, center of mass - how they differ. C. Res of different teeth, C. Res in different perspectives, changing location of C. Res.

Translation, definition of C. Res based on translational displacement, translation could occur in any plane.

Part translation and part rotation from eccentric force application, translation in one perspective may cause part translation and part rotation in another perspective.

Moment = product of force and its perpendicular distance from C Res, measuring units, how the magnitude of the moment can be altered in different ways, how to predict the direction of a moment.

Moment from a force couple, pure rotation,  $M_f$  and  $M_c$ , the couple may be applied anywhere on the body, and the result always is rotation around the C. Res, couple is a 'free vector'.

Rotation (around long axis), 'tip' (or changed angulation) and 'torque' (or changed inclination) in the clinical practice are all rotations from mechanics point of view.

First, second and third order tooth displacements; and archwire bends, force or couple application which effect these tooth displacements.

Some other commonly used terms: activation and deactivation forces, teeth movements in mesial and distal directions, Inclinations and angulations, class I, class II or class III forces, Statically determinant / indeterminate (determinate / indeterminate) systems.

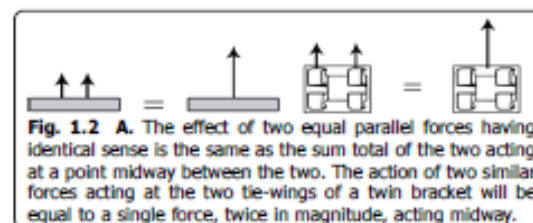
Strictly speaking, forces are *measured* in terms of Newtons or dynes. A force is calculated as the product of mass and acceleration ( $F = m \times a$ ). One Newton is the force magnitude which, when applied to a mass of 1 kg, would result in an acceleration of 1 meter/second/second along the line of action. One dyne is the force required to accelerate a mass of one gram by one centimeter per second/second. However, in orthodontic practice, mass and acceleration are not very relevant and, therefore, could be ignored. Thus, force measurement is often expressed in terms of grams (which, in reality, are units of mass). One Newton is approximately equal to 100 grams (See the box at the end of this chapter for conversion of units).

The force generating components of an appliance are called *active elements*. Various types of active elements are employed in the fixed appliances such as archwires, springs, screws, elastics and elastomeric rings, threads, chains etc. Forces could arise because of *tension, compression, bending or torsion* in the active members. The resulting deformations, trying to regain the original forms, generate forces. While bending and torsion are relevant to archwire deformations, tension and compression are related to other components. Archwires and their deformations causing force generation are described in the next chapter, while actions of loops will be discussed in a later chapter.

We frequently apply more than one force in our practice. When two forces are applied simultaneously, they could be parallel to each other or they could be non-parallel. Both these applications need to be understood well.

### Parallel force application

We will first consider the application of two equal parallel forces having the *same direction and sense*, since this application is easier to understand. Their net effect will be the same as their sum total acting at a point midway between the two points of force application. This is relevant in case of twin edgewise brackets (Fig. 1.2 A). For instance, if a tooth is placed

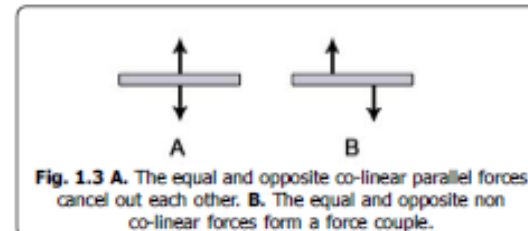


labial or lingual to the arch (but is not rotated), and its two bracket tie wings are tied to the archwire, it will experience a push or pull at two points. The net effect will be felt at the center (Fig. 1.2 B).

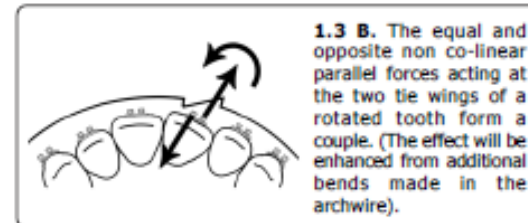


**1.2 B.** The two tie wings of a twin bracket on an instanding lateral incisor experience equal parallel labially directed forces. The net effect is felt as a force midway, twice in magnitude.

When two equal and parallel forces act in *opposite sense*, they form a special application named as a force couple. A *force couple* consists of two forces parallel to each other, equal in magnitude, and having opposite senses; but equally importantly, having *non co-linear* lines of action. (The non-co-linearity is an important aspect of a couple but is often missed. Without it, the two forces will cancel out each other as shown in Fig 1.3 A. Consequently, there will be no net effect.) For

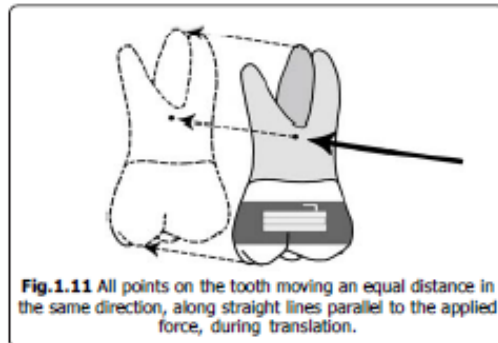


generating a force couple, a *two point contact* between the active element and the bracket-tooth complex is needed. Further, the relation of the former to the latter should be such that it acts in one direction at one of the point-contacts and in the opposite direction at the other point-contact. When the tie wings of a rotated tooth are ligated to the archwire, the tooth will experience a push at one point and a pull at the other (Fig. 1.3 B).



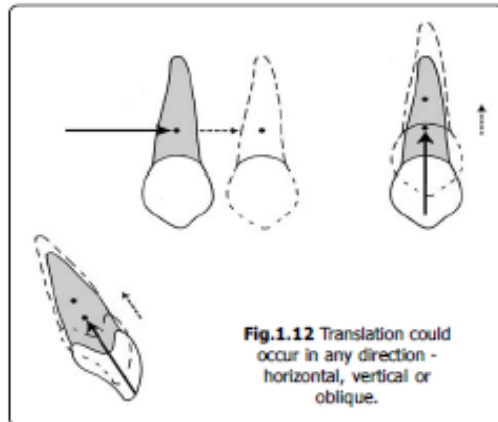
### Translation:

When a force acts *through the C Res*, it causes translation of the body. In translation, all points on the body move an equal distance in the same direction, along straight lines parallel to the line of force. (Fig.1.11) Vice versa, the nature of translation could be used in *defining the Center of resistance* in a more precise manner. Center of resistance is that point within the body through which a force has to pass to cause its translation.



**Fig.1.11** All points on the tooth moving an equal distance in the same direction, along straight lines parallel to the applied force, during translation.

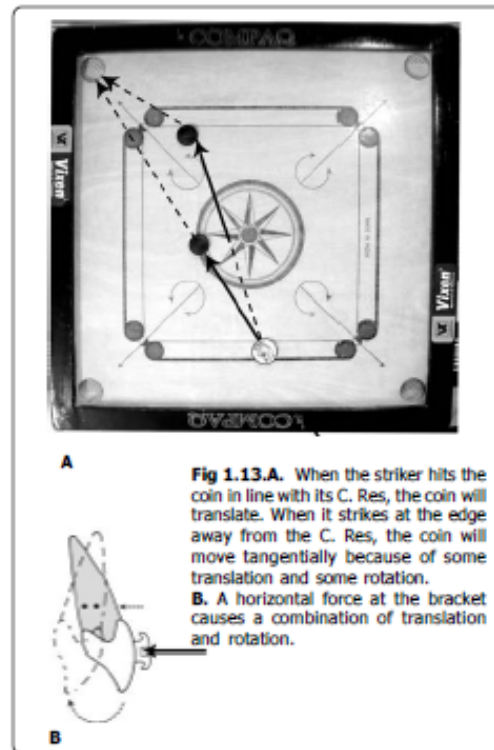
Remember that translation or bodily displacement *could occur in any plane* – horizontal, vertical or oblique depending on the direction of the force. Often, students have a mental picture of a tooth moving mesio-distally or facio-lingually as the translational movement, but a canine intruding vertically, or an upper incisor intruding in an oblique direction, are also examples of translation (Fig.1.12).



**Fig.1.12** Translation could occur in any direction - horizontal, vertical or oblique.

### Part translation and part rotation:

What happens with *eccentric force* application? When a force acts away from C Res, it causes *part translation and part rotation*. Is this difficult to understand? Not really, if you have played or even watched the game of carom. When the striker hits in line with the center of the coin, the latter will move in the direction of the force application. If the striker hits at the edge of the coin i.e., away from the center of the coin, the coin will move tangentially because it translates to some extent but also spins i.e. rotates (Fig. 1.13 A). Mulligan<sup>11</sup> described this part translation / part rotation effect of eccentric force application using the billiards cue-ball analogy. To consider a clinical application, when a retractive force acts at the bracket of the upper central incisor, the force application is eccentric. The tooth retracts (translates) to some extent as can be seen from a horizontal movement of its C. Res; but it also rotates in crown lingual/root labial fashion.



**Fig 1.13.A.** When the striker hits the coin in line with its C. Res, the coin will translate. When it strikes at the edge away from the C. Res, the coin will move tangentially because of some translation and some rotation.

**B.** A horizontal force at the bracket causes a combination of translation and rotation.

## Evolution of Fixed mechanotherapy for applying refined mechanics in Clinical practice

### CONTENTS

Refined application of mechanics to enhance ease, accuracy and predictability.

How efficacy of appliances for applying force couples in different planes was improved in the appliances developed by Angle, Case and Begg.

Refinements in the edgewise brackets: Original edgewise brackets, efficacy of narrow v/s wide and single v/s twin brackets in applying torque, tip (importance of contact angle and moment arm) and rotational control. How mesio-distal and rotational control were enhanced in different designs. Importance of inter-bracket distance. Why changes in the size of the slot was conceived. Preferences for 22 and 18 slots. Different slot size brackets on different teeth in the same appliance and rationale behind such use.

Pre-adjusted edgewise appliances (PAE): Evolution of concept ending in Andrews' 'straight-wire' appliance. Common features of PAE appliances. Why first second and third order bends were repeatedly needed in standard edgewise appliances, and how they were eliminated in PAE appliances. Meaning of terms 'torque in the base/in the face' and 'straight wire'. Different versions of PAE. Benefits of PAE appliances from mechanics point of view: precision, predictability and efficiency. Can they eliminate wire bending altogether? Is their biomechanics different?

Recent innovations in bracket designing, mechanical advantages of self-ligating brackets.

Archwires; general features and functions. Beams freely supported or fixed at two ends. Different alloys from which archwires could be made. General properties of archwires. Mechanical properties of Archwires as related to clinical usefulness: Stiffness/springiness, working range, resilience, formability, strength, springback (elastic behavior of the archwires).

Graphic depiction of elastic properties from the force-deflection or stress-strain diagrams. Proportional limit, yield point, point of clinical loading, failure point, ultimate tensile strength, elastic modulus. How they are related to archwire properties. Cold working and annealing. Elastic and plastic deformations. Load (or force) deflection rate (or ratio). Effect of cross-sectional geometry (and interbracket distance) on elastic properties. Mechanical properties as related to archwire materials and manufacturing process.

Special properties of NiTi wires: phase transformation from austenitic phase to martensitic phase (what these terms refer to), clinical usefulness. Thermo-elasticity and pseudo-elasticity, shape memory, super-elasticity, hysteresis, "Variable cross-section orthodontics" v/s "Variable modulus orthodontics" and "Variable transformation temperature orthodontics".

Indications for the use of different wires.