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ORIGINAL ARTICLES

PRIMARY LINES OF FORCE OF THE PERMANENT TOOTH*

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BY PRIMARY lines of force is meant the lines of first importance. They are considered as principal and fundamental lines peculiar to the individual tooth. In this presentation they must needs be elementary. The definition of force is that which changes or tends to change the relative condition as to rest or motion between two bodies. In this article two factors in the function of the teeth are dealt with, to-wit, force and tooth. To emphasize the identity of each and their equal importance, reference is made to a recent article wherein definitions of orthodontia are given; one as the "correction of malocclusion" and the other as "that which treats of forces controlling the form of the dental arch." One lays stress on position, the other on force. It is evident neither force nor form can be considered alone, but both are indispensable in the function of the teeth. In the mind of the writer, orthodontia is the science which treats of function in relation with the position of teeth. Instead of malocclusion, we refer to lost or disturbed function; and instead of correction, we refer to improved function. In improved function we have greater efficiency and in greatest efficiency, beautiful form and beautiful expression.

While the lines of force herein explained represent but a few of all in occlusion, they are of considerable importance in regard to the position of teeth. In the study of the position of teeth the lines of force are ascertained by the relative position of the teeth and their individual forms. Up to the present time this is a knowledge based mostly on experience and observation in treatment of cases. There is little data dealing with this subject, yet these lines of force are most potent factors in the maintenance of the tooth in proper equilibrium. The preservation of the health of the surrounding tissues depends to a very great extent on the proper delivery of force to it.

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A knowledge of forms of parts is imperative to a proper understanding of this subject. The form of the tooth, crown and root, and the structure of the supporting tissues are such that force applied to the crown of a tooth in the natural and most effective manner shall be opposed by forces of supporting tissues, likewise of special design, conforming to such demands. The form of the root being unchangeable, there is only one position for it to occupy in proper function, reference being hereby made to Angle's "Line of Occlusion." Herein is a fundamental principle in the study of all dental operations. The human denture is composed of teeth designed for a varied usage, and accordingly the individual tooth presents many forms. In form and function no two teeth of an entire denture are exactly alike. Each tooth has an identity of its own. It must be borne in mind that the tooth is but a part of a great machine, a machine of itself, as dependent on other parts as the whole is on its parts. We will consider the tooth apart from its neighbors, and study it as a unit of itself. The single tooth is not to be thought of as an inert mass inserted in inert matter but a living part of a living body, a part used principally in the mastication of food, with lines and surfaces receiving and transmitting force in a variety of directions. Strictly speaking there is no such thing as a stationary tooth in the living being. Forces are continually at work causing movement of all parts of the body, and the tooth is no exception. The position of equilibrium of a tooth may be said to express the forces acting upon it.

Interest is to be confined to a study of directional forces, lines and surfaces of the permanent tooth in normal function, taking for description teeth not belonging to a particular type, but those described and illustrated in text books on dental anatomy. The purpose is to include such data that a more specific description of forces and a better understanding of the resolution of forces may be had, or in other words that more basic principles be formulated from which to make deductions.

In the study of lines and surfaces of the human teeth practically no straight lines are to be found. Therefore a strictly accurate description regarding their part in the promotion of force is beyond the intent of this article. But bear in mind force travels in a straight line (Newton's first law). Is it not a fact that in practice we consider inclines as without curvature? The specific direction of force will vary according to the variation in form of the tooth. A liberal interpretation will necessarily have to be made of that which is to follow and for ease and clarity straight geometric forms replacing the curvatures will be used. It will be necessary to introduce a few new terms to properly present the subject.

The position that this subject bears to general physics is quite obvious. However, that a clear understanding may be had, it may be best to start with the terms and definitions in physics applicable to our subject. Of the various subdivisions of general physics, our subject is included in mechanics, which treats of motions of bodies and the causes of changes in these motions.

Force is whatever changes or tends to change the motion of a body, or that which produces acceleration. The same thought is conveyed by the definition given in the first part of this article but given again for emphasis.

There are two kinds of motion, translation and rotation, the former when

every straight line in the body remains parallel to its original position and the latter when all points in the body travel in circles the centers of which lie in a straight line; this line is called the axis of rotation.

A point or body is said to have one degree of freedom when its motion is confined to a definite line; two degrees of freedom when confined to a definite surface, and three degrees of freedom when not restricted in any way. Note the structure of the tooth, its root and surrounding parts and it will be observed that the tooth has freedom in either of the three degrees. The conic root seated in the conic socket, or alveolus, allows for this.

A force is always accompanied by a counterforce or, we may say forces act in pairs.

When two equal and opposite forces act on a body they are in equilibrium.

It may be well to bear in mind Newton's three laws of motion as they will be used throughout our study.

First Law.—Every body persists in its state of rest or of uniform motion in a straight line unless it is compelled by some force to change that state.

Second Law.—The rate of change of the momentum of a body is in proportion to the force acting on the body and is in the direction of the force.

Third Law.—Action and reaction are equal and opposite.

Force is completely defined when its magnitude, its direction, and the point at which it is applied are given.

The resultant of two forces is defined as that single force which will produce the same effect upon a body as is produced by the joint action of the two forces.

The resultant of two similarly directed forces is equal to the sum of the two forces.

The resultant of two oppositely directed forces applied at the same point is equal to the difference between them, and its direction is that of the greater force.

The resultant of two equal and opposing forces is zero. Two equal and opposite forces not in the same line constitute a *couple*.

The equilibrant of a force or forces is that single force which will just prevent the motion which the given forces tend to produce. It is equal and opposite to the resultant.

The component of a force in a given direction is the effective value of the force in that direction. Whenever a force acts upon a body in some direction other than that in which the body is free to move, it is clear that the full effect of the force is spent in two directions, both of which forces are components of the single force. To ascertain the components of a force delivered to an inclined plane we may use the parallelogram method of resolution of force. (Fig. 1.) Let *AB* represent an inclined plane and *CD* force applied. The force applied is free to move in the direction of *B*. Hence *DE* represents the one component of *CD*. Using the force *DH* as the diagonal, a parallelogram *DEHG* is drawn—the side of the parallelogram *DG* represents the other component of *CD*, or the force spent at *D* in the direction *DG* first mentioned as the direction in which the force was not free to move.

Functional movement of the tooth in its alveolus is allowed by the periodontal membrane. Be it understood that the tooth is in equilibrium and changes

UPPER CENTRAL INCISOR

We will consider the upper central incisor from three aspects, mesial, labial, and occlusal or incisal. In order to present vividly the primary lines of force, a separate drawing is made of each view, also a drawing for each line of force. Bear in mind we do not consider magnitude but only direction of line of force. The occlusal and primary lines of force of the upper central incisor that are presented as directed vertically and horizontally are as follows:

Primary Lines of Force of the Mesial Aspect.

1. Principal line of force.
2. Vertical line of force to inclined plane.
3. Horizontal line of force.
4. Horizontal line of force to inclined plane.

Primary Lines of Force of the Labial Aspect.

5. Vertical line of force, mesial or distal, of principal line of force.
6. Vertical line of force to incline formed by junction of incisal and distal surfaces.

Primary Lines of Force of the Occlusal Aspect.

7. Horizontal line of force, mesial or distal of the principal line of force.
8. Horizontal line of force to incline mesial or distal of the principal line.

MESIAL ASPECT OF UPPER CENTRAL INCISOR

Referring to the mesial aspect, the upper central incisor is described as follows: "The root is conic in form, its base directed downward, its apex upward. The general form of the crown is that of a double inclined plane, or wedge-shape, the cutting edge representing the junction of the two sides of the incline, one of which looks anteriorly (labial) and the other posteriorly (lingual). The base of the wedge is directed upward and partakes of the contour of the neck of the tooth."

Using the outline as described of the upper central incisor as in Fig. 2 and superimposing two isosceles triangles, one for the root of the tooth *ABC* and one for the crown *ACD*, each having the same base at the neck of the tooth, the sides represent diagrammatically the general form of the tooth from mesial or distal aspect, and for our purpose this will be considered as representing a cross section of the tooth midway between the mesial and distal surfaces.

As the area of *ABCD* represents the body of the tooth and as heretofore mentioned transmits force from the occlusal to the maxillary or vice versa, it is necessary that parallel inclines *EF* and *GF* representing the cross section of the alveolus be drawn also. Be it remembered that maxillary forces are the equilibrants of occlusal forces.

(1) *Principal Line of Force.*—Using the aforementioned outline and drawing a line from the apex of one triangle to the other *BD* (Fig. 3) both triangles are bisected. This line, as has already been mentioned, represents the principal line of force and also the line of movement of the tooth vertically. Force in the direction of *HD* applied to the angle at *D* will cause a vertical

translation of the tooth in that direction, a primary movement vertical and maxillary. As in translation all lines of force move in parallel lines, we will draw two lines MK and LJ to represent lines of force directed to incline EF and GF . However, as the entire body of the tooth transmits force to these maxillary inclines, similar lines directed to any point along the inclines might be used. Force MK is resolved into two component forces, one in the direction of F and one in the direction of K' . The lines JJ' and JF represent the component forces of the line LJ . The maxillary equilibrants may be represented by $F'F$, for the line of force HF and for the resultant of the components JF and

Fig. 2

Fig. 3

KF . The maxillary equilibrants of the component lines of force striking the maxillary inclines may be represented by the lines $J'J$ and $K'K$. The translation of the tooth is vertical and in a maxillary direction. Herein is primary movement and no coincident movement.

(2) *Vertical Line of Force to Inclined Plane.*—The primary line of force HL (Fig. 4) parallel to the principal line of force directed to the incline DC is resolved at L into components, one LP in the direction of P and one LO in the direction of O .

It is evident that force in the direction of O will produce rotation of the tooth with an axis represented by a center of attachment at B . Primary movement of the tooth is in the direction of the primary line of force HL , vertical and maxillary. The coincident movement is in line with LO . However, the com-

ponent LO may be projected to the incline EF as at O and here resolved into two components, one on the incline in the direction of F and one in the direction of P . Motion of the tooth occurs primarily in a maxillary direction and incidentally labially or lingually. The maxillary equilibrants are represented by the lines $F'F$ and PO . If a primary line of force M be directed to the other incline DA , equidistant with force (HL) from the principal line of force, and supposing both inclines to be alike it will become resolved into components as above described. If it be made to act with the other force H , the components meeting at O effect a resultant represented by the principal line of force. In this

Fig.4

Fig.5

latter case the primary movement of the tooth is vertical as in the description of the line of force preceding and no coincident movement is effected.

(3) *Horizontal Line of Force*.—A primary line of force JD (Fig. 5) directed at right angles to the principal line will cause rotation of the tooth with the axis at B . Hence primary movement is facial or lingual. The line of force LD projected to incline EF is resolved into components, one in the direction of E , and the other in the direction of K . The maxillary equilibrant is represented by the line KD . The consequent primary movement of the tooth is one of rotation with an axis as at B lingually or labially. The tooth is rotated with an occlusal translation effecting a coincident movement occlusally. It is obvious that a like force in the opposite direction to JD as PD will produce a resultant of zero or no movement.

(4) *Horizontal Line of Force to Incline.*—The primary line of force HJ (Fig. 6) directed at right angles to the principal line of force and to the incline CD is resolved into components, one in the direction of D as JK and one in the direction of L . This component force JL projected to incline FE is resolved into components LM and LN . The maxillary equilibrant of LN is represented by line NL . It will herein be noticed that motion of the tooth is produced primarily labially or lingually by rotation at B and coincidentally in a maxillary direction. A concomitant and similar force OP to the incline AD opposite to HJ will result in no primary movement of the tooth but in a coincident movement

in a maxillary direction by effecting a resultant at L represented by the principal line of force DB .

LABIAL ASPECT OF THE UPPER CENTRAL INCISOR

The labial surface of the crown of the upper central incisor is described as resembling an imperfect quadrilateral. The root as before mentioned is conic in form, hence an isosceles triangle ABC may be superimposed over the outline of the central incisor as in Fig. 7. A line bisecting this triangle as BD is used to represent the principal line of force of the labial aspect. Maxillary inclines EF and GF are shown in Fig. 8. It will be noted the distal incisor angle is represented by a line EF which will be referred to later.

(5) *Vertical Line of Force Mesial or Distal of the Principal Line of Force.*—A primary line of force HK (Fig. 8) parallel to the principal line of force and striking the line AC representing the incisal edge of the tooth as at K , is directed to the maxillary incline GF . Slight rotation is effected by this line of force being to one side of the principal line DB causing a resolution of the line of force on the incline FG , into components, one in the direction represented by lines KJ and one in the direction of F . Resultant movement of the tooth is in the direction of F and the opposite incline EF . The resolution of the component force KF is shown on the incline EF as at O , one component in the direction of P and one in the direction of F . The equilibrants are represented by JK , $F'F$ and PO . Primary movement due to this force HK is in a maxillary direction with coincident movement of rotation. A line of force repre-

sented by the line *IM*, directed to an equal distant point as that of *HK*, from the principal line and on the line *AC* is resolved into components similar to those of *HK*. The combined action of the two forces *HK* and *IM* is that of a primary vertical translation in a maxillary direction. In this case there is no coincident movement.

(6) *The Vertical Line of Force to Inclined Plane of Distal Incisal Angle.*—It is believed force delivered to incline *FE* (Fig. 9), in fact representing a rounded surface, so much more rounded as compared with mesial incisal angle, is of such significance as to be worthy of consideration. Such a form apparently is of value in the movement of eruption, in maintaining approximal con-

tact, and in conjunction with a like force of the other central incisor, it is of value in the equilibrium of the tooth. It may be observed that the effect of this line of force is similar in resolution to that described under the heading of primary line of force (No. 2). Line of force *HJ* is resolved into components, one in the direction of *E*, and one in the direction of *O*. The effect of the movement of the tooth in the direction of *O* on the inclined plane *KS* is a resolution of that force represented by the line *JO* into its components, one in the direction of *S* and one in the direction of *P* as the line *OP*. The primary effect of this force *HJ* is primary movement vertically and in a maxillary direction with coincident movement mesially.

THE OCCLUSAL ASPECT OF THE UPPER CENTRAL INCISOR

This view presents for our consideration a root whose outline is described as that of "a rounded triangle, one side of which faces a labial, one in a mesio-lingual and one in a disto-lingual direction. This triangular outline usually

Fig. 10.

continues throughout the entire length of the root." Using the above description for the outline as in (Fig. 10) *B* represents the root; *A*, the alveolus; and *J* an outline of a cross section about midway between the incisal edge of the crown of the tooth and base of the root. We will superimpose a triangle *DEF* for the root and *GHI* for the alveolus. Line *KS* is drawn about midway between labial and lingual surfaces of the crown of the tooth. The line *RS* is used to represent an incline mesial or distal of the principal line.

(7) *Horizontal Line of Force Mesial or Distal of the Principal Line.*—The primary line of force represented by line *DV* in (Fig. 11) coming in contact with the line *KS* distally of the principal line which is represented by *N*, effects a rotation on the axis *N*. This force projected may be resolved into components as at *JL* and *M*. The force *D* projected to *J* on the incline *HI* is resolved into components, one in the direction of *I* and one in the direction of *O*. Resolution of lines of force are shown at *L* and *M*. From the above aspect primary movement is that of rotation with coincident movement as in this case lingually and to the opposite side mesially. This line of force should not be confounded with lines described as number 3 and 4. Force *TU* parallel to

force DS but in opposite direction will form what is called a couple. The couple effects simply rotation. This primary line of force in conjunction with an opposite line TV effects no primary movement of rotation. Primary line of force YK equidistant with the line DS from N effects in unison primary movement of the crown of the tooth lingually in this case with no coincident movement.

(8) *Horizontal Line of Force to Incline Mesial or Distal of the Principal Line.*—In Fig. 12 the line RS is used to represent the incline as viewed from the occlusal aspect. The primary line of force AB is resolved into components, one in the direction of S and one in the direction of O . While the primary movement is one of rotation, the coincident movements of the crown of the tooth are mesial and lingual, or in a distal and lingual direction if it be mesial to the axis of rotation. This line of force, if projected to the incline HI , may be resolved into components as in the description of the line preceding. Line of force LM on the incline WK and in the opposite direction of AB forms a

Fig. 11

Fig. 12

couple with primary movement of rotation of the tooth. Line of force XZ opposite to the line AB effects coincident movement of the crown of the tooth in this case mesially.

In conclusion it may be said that it was deemed expedient to curtail description as much as possible in order not to be confusing and hence certain omissions have been made. The coaction of forces make a description and comprehension of each isolated force difficult, and combinations of different primary forces have for reasons set forth not been mentioned. However, an outline of primary lines of force, such as illustrated here in the case of the upper central incisor, furnishes fundamental principles on a more comprehensive scale than those heretofore described in the occlusal relations of the teeth. Functional improvement being our aim in practice, function is the basis for treatment. In the proper conception of function, lines of force such as these that have been mentioned, as well as those that are to follow, would have their proper relation neither exaggerated nor minimized among all other lines of force effective in the promotion of the position of teeth. The application of a

similar systematic arrangement of primary lines of force may be followed in the description of the other teeth of the dental apparatus with such changes as the individual tooth may warrant. This requires further elucidation of the subject.

BIBLIOGRAPHY

- Broomell and Fischelis: *Anatomy and Histology of the Mouth and Teeth*, 1910, P. Blakiston's Son & Co.
 Duff: *A Textbook of Physics*, 1918, P. Blakiston's Son & Co.

ORTHODONTICS, A STUDY IN SIX DIMENSIONS*

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PROVISIONALLY and at the moment I define orthodontics as:

The study of the normal relations of the dental arches in themselves and in their relation to a normal facial configuration; the study also of the nature and causation of abnormalities and the means of correcting them so as to restore as far as possible normal relations to the arches and a normal configuration to the face.

Definitions such as this have at times their uses, but with the ever widening circle of our knowledge they become in time antiquated and are then relegated to that dim twilight land the land of the ineffective and the obsolete.

Each of the two parts of the masticating mechanism which we call the dental arches consists of sixteen minor elements, each of which may vary within wide limits from their normal relations to one another, and logically there can be no perception and recognition of the abnormal which is not based absolutely upon a preconceived knowledge of the normal. It is doubtless the general consciousness of this which is prompting the admirable studies which are now being made of the detailed relations of various elements in the normal arches of man. In pre-Darwin days, it was usual to speak of the normal as being grouped into different "types," but the infinite variations found in these types was at first the very basis on which Darwin slowly built up his great theory and afterwards was one of the constant features upon which that theory focused the attention of mankind. And these variations, so infinite in their number, so slight and so subtle in many of their differences necessitated and compelled a different method of regarding what we call the "normal." The old idea of normal "types," or at any rate many of the connotations attaching to this term, has largely passed away and what we call the normal is now regarded by modern biologists and anthropologists as what is called "an array of variates." The variations comprised in any array of variates which together we call the normal, shade gradually by minute differences into what we call the abnormal, and the line of demarcation between the two has never in reality anything about it like the clear-cut outline of a text book diagram. There is a graded transition between the normal and the abnormal through which the one passes almost imperceptibly into the other. If this be so it becomes obvious at once that a study of the variations in

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