

## Anchorage in Orthodontics: Three-dimensional Scanner Input

Fidele Nabbout<sup>1</sup>, Pascal Baron<sup>2</sup>

<sup>1</sup>Department of Orthodontics, School of Dentistry, Lebanese University, Beirut, Lebanon,

<sup>2</sup>Department of Orthodontics, School of Dentistry, Toulouse III University, Toulouse, France

ABSTRACT

**Aims and Objectives:** The aim of this article is to re-evaluate anchorage coefficient values in orthodontics and their influence in the treatment decision through the usage of three-dimensional (3D) scanner.

**Materials and Methods:** A sample of 80 patients was analyzed with the 3D scanner using the C2000 and Cepha 3DT softwares (CIRAD Montpellier, France). Tooth anatomy parameters (linear measurements, root, and crown volumes) were then calculated to determine new anchorage coefficients based on root volume. Data were collected and statistically evaluated with the StatView software (version 5.0).

**Results:** The anchorage coefficient values found in this study are compared to those established in previous studies. These new values affect and modify our approach in orthodontic treatment from the standpoint of anchorage.

**Conclusion:** The use of new anchorage coefficient values has significant clinical implications in conventional and in microimplants-assisted orthodontic mechanics through the selection and delivery of the optimal force system (magnitude and moment) for an adequate biological response.

**KEYWORDS:** *Anchorage, orthodontics, three-dimensional scanner, tooth anatomy*

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### INTRODUCTION

In their daily practice, orthodontists are constantly facing the problem of anchorage.<sup>[1,2]</sup>

Anchorage is the resistance to movement of the teeth that we do not wish to move (stable anchorage). It is also the resistance of the tooth or teeth to move (mobile anchorage).

The purpose of this study is to redefine anchorage values and concept in orthodontics and their impact on treatment.

The only study available on the subject was given by Jarabak and Fizzell<sup>[3]</sup> in 1972 and was based on estimation without measurements.

At the present time, with the technological upgrading of the imaging techniques such as three-dimensional (3D) scanners, more details are provided, and accordingly, better dental root volume assessment and high precision of true anchorage values could be performed.

The benefit of the 3D scan is to calculate the accurate dental root volume leading to a more precise anchorage coefficient.

This approach will have a direct consequence on the choice of force magnitude (the lowest force possible), to preserve the biological anchorage represented by the teeth.

Understanding biomechanics of tooth movement and the periodontal system (periodontal ligament, bone) are important parameters in estimating anchorage needs but remain insufficient for a precise anchorage evaluation in static and dynamic movement.<sup>[4,5]</sup>

### MECHANICAL ASPECTS OF TOOTH MOVEMENT

Tooth movement is mainly related to the displacement resistance of each tooth engaged either in movement or in fixed position.

To be accurate, a full analysis of the whole force system is necessary (the resultant force and the resultant moment of each tooth) to:

**Address for correspondence:** Dr. Fidele Nabbout, Department of Orthodontics, School of Dentistry, Lebanese University, Beirut, Lebanon.  
E-mail: fnabbout@yahoo.fr

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1. Evaluate the tension applied to each square millimeter of the root and thus to model the bone changes
2. Determine the resultant forces and moments at the center of resistance of the tooth.<sup>[6-8]</sup>

In this article, only the resultant forces and moments will be considered.

Newton's third law of motion (action and reaction) is directly related in day-to-day orthodontics. When a force is applied to bring together two structures, the possible displacement of one of the two structures will be as large as the other structure remains still.

Anatomically, some points are known to be stable, i.e., skull for headgear support and mandible in anchorage preparation.<sup>[9-11]</sup>

A solid moves, when a force greater than the resistance is applied.

In orthodontics, two types of resistance forces are defined:

1. Stable resistance (SR) or resistance to movement (anchor unit)
2. Mobile resistance (MR) or ability to movement (moving unit).

#### *Anchor unit*

It represents the necessary anchorage to displace a single tooth or a segment of teeth. It is traditionally provided by a group of teeth or cranium support.

Nowadays, the whole concept of anchorage has changed with the advent of microimplants providing an absolute anchorage.<sup>[12-14]</sup>

#### *Moving unit*

It represents the tooth to be displaced. During intermaxillary mechanics or incisor retraction, and according to De Nèvrezé formula, the reciprocal resistance value of two segments of teeth, one stable and one mobile, produces the expected movement.

According to De Nèvrezé, forces are divided into stable and MR.<sup>[15]</sup>

SR = anchorage teeth.

MR = teeth to be displaced.

Moving Force (MF) = inducing different types of tooth movement such as bodily movement, tipping, or rotation.

The stable and mobile tooth resistances depend on several factors: age and gender, Sigaud facial type, dentition and type of movement.

De Nèvrezé defines the following optimal situation:

The magnitude of the MF is insufficient to displace an anchorage of high value (SR) but is sufficient enough to displace the teeth to be moved (MR) ( $MR < MF < SR$ ).

This equation is valid when the SR is much higher than the MR ( $SR \gg MR$ ).

### **BIOLOGICAL ANCHORAGE**

Biological anchorage is the anchorage of the tooth itself with its surrounding structures such as periodontal ligament, alveolar bone, as well as the muscular system that is able to resist orthodontic forces.

The value of tooth anchorage is related to its radicular length, volume, and number of its roots. It is also related to its position on the arch (e.g., a distally tipped tooth is more resistant according to Tweed concept of anchorage preparation).<sup>[10,11,16]</sup>

Different definitions were given to tooth resistance to displacement.

For Freeman, the root surface area in mm<sup>2</sup> should be considered,<sup>[17]</sup> while for Jarabak, it is the length of the root that should be taken into account; a long root is more resistant than a short one.<sup>[3]</sup> For others, it is the surface area projected on a perpendicular plane to movement, considering that only the compressed area is the resistant factor to displacement.

For the authors, the best estimation of anchorage is radicular volume providing a 3D approach of the root in its socket. Since Archimedes, it is known that any displacement of an object implicates the idea of volume.

The aim of this study is to calculate roots volume to define new values of the anchorage.

### **MATERIALS AND METHODS**

#### **MATERIALS**

This retrospective study evaluated achieved 3D full skull scan of 80 patients (34 males and 46 females) with an average age of 28 years (range: 15–65) taken for diagnosis purposes (e.g., maxillary sinus affection, maxillofacial dysmorphism...) in Clinic Pasteur Hospital (Toulouse, France).

Consents of the patients were obtained after being informed that their images might be anonymously used for research purpose at any later stage. The study got the approval of the Institute of Clinic Pasteur.

The principle of "As Low As Reasonably Achievable" was all the time respected.

The exclusion criteria included patients with bilateral agenesis or teeth extraction on any of upper or lower arches.

The data obtained were statistically analyzed using StatView software version 5.0 (SAS Campus Drive Cary, North Carolina, USA).

## METHODS

### Capture of 2D data

All the 3D scan examinations were performed using a CT TWIN FLASH (ELSCINT, Haifa, Israël). Each radiography was taken with patient in supine position.

Using a “scout view” of the lateral skeleton, we programmed helicoidal capture from the chin to the top of the eye sockets.

Capture time varied between 35 and 55 s according to the extent of the helicoidal capture.

The usual technical conditions were:

- 250 mm is the diameter of the field acquisition
- 1.3 mm is the collimation of X-ray beam
- 0.9–1.8 mm is the thickness of the reconstructed cut
- 90 kV is the voltage
- 512/512 is the matrix of the reconstructed cut
- 0.7 Mas is the pitch
- For 100 Mas, 4 mGy of radiation is delivered per blade volume
- For 75 Mas, 3 mGy of radiation is delivered per blade volume (information from ELSCINT).

In comparison, the radiation delivered for 60 Mas and 60 kV by a conventional teleradiographic device is 1.5 mGy when the X-ray source is located at a distance of 4 m, and 6 mGy at a distance of 2 m. The delivered radiation for 60 Mas and 60 KV for a conventional orthopantomograph is thus 13.5 mGy (information supplied by Philips).

The primary beam of the CT scan avoids the thyroid. The original 2D CT scans are transferred by Ethernet network to a workstation. After being converted, they are processed by C2000 software developed by CIRAD at (Montpellier France).

### The C2000 software

The software developed by CIRAD at using scanner-generated data provides images and 3D biometry of the anatomical features.

In this study, the database used by the software comprises axial time division multiplexing slices of the inferior-superior dimension.

C2000 generates 3D images from the CT data using the thresholds method and the diving cube to define areas with identical values within a volume. In this way, it is possible to reconstruct the maxillofacial anatomical features (teeth or roots, bones, and skin) [Figures 1 and 2]. 3D muscle reconstruction can also be performed. Information technology can thus be deployed to isolate or, on the contrary, combine each of these features with more or less transparency and depth in relation to each of the other.

### Teeth segmentation

On the native slices, C2000's cephalometric module segments the teeth, i.e., separates and attributes the different dental zones [Figure 3].

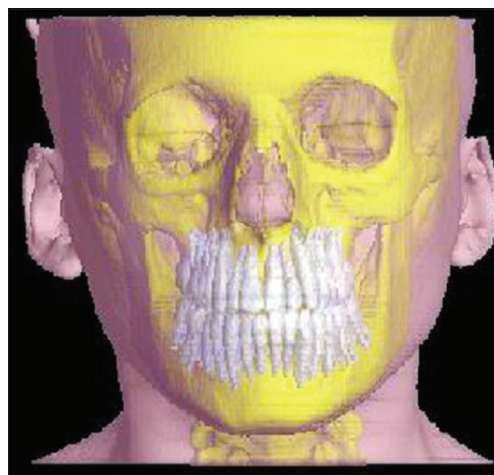


Figure 1: Reconstruction of teeth, bone, and soft tissue



Figure 2: Reconstruction of roots, bone, and soft tissue

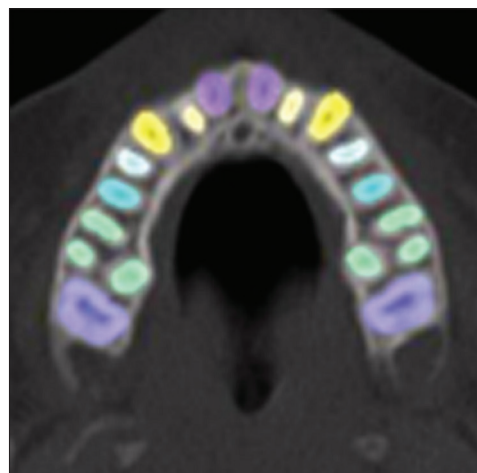


Figure 3: Axial cut illustrating segmentation of teeth

Once the segmentation of the teeth is performed, C2000 software can calculate the volume expressed in voxels and in cubic millimeters, the density and the gravity center, for the different dental quadrants as well as the complete dental arch.

In this study, two selection techniques were used.

#### Manual selection

For each slice, the segmentation and contouring of the different anatomical structures is achieved.

The different segment, i.e., the different anatomical structures are segmented and contoured for each slice. The operator then attributes each anatomic structure to its appropriate zone.

#### Semiautomatic selection

The thresholding technique can help to recognize and confine the teeth.

Thresholding is a simple technique designed to extract from a native image, the pixels with a density falling within certain limits. This processing makes it possible to select dots on the image according to their level of gray. Different density zones can then be distinguished from bone and from one another. The operator, however, needs to be involved as he/she attributes a specific segment to the corresponding teeth in the event of two teeth being in contact with one another.

According to the digital data of the bidimensional axial cuts, C2000 software can realize a 3D reconstruction. After the selection, the software allows tooth volume calculation in voxels and  $\text{mm}^3$ .

Based on the numeric data of the bidimensional axial cuts, C2000 can realize the reconstruction. After the segmentation, C2000 allows the calculation of teeth volumes, in voxels and  $\text{mm}^3$ .

#### Segmentation of roots and crowns

Root volumes are calculated using the same procedure but only by segmenting the slices including the root.

The axial cut between root and crown is defined by the C2000 software using computer tools to distinguish the gray levels [Figure 4].

The definition is therefore based primarily on density-related factors (enamel density being higher than other dental structures). Verification by the operator of the anatomic segmentation is performed visually.

The crown is obtained simply by subtracting the root from the remainder of the tooth.

By segmenting each 2D axial slice of the structures belonging to each tooth or root, the C2000 software

provides a 3D reconstruction of the whole teeth or the root the C2000 software provides a 3D reconstruction of the whole teeth or the roots alone.

#### Measurements

Mean values and standard deviation of, respectively, root, crown, and entire measurements and volumes of each tooth are calculated by C2000 software and matched to the available bibliographic data.<sup>[18,19]</sup>

#### STATISTICAL ANALYSIS

The average values of root, crown, and overall volumes of each tooth with their standard deviations are calculated.

Difference between the two sides (right and left) is slight and does not affect the anchorage values. For this reason, the difference in tooth size on each side was not considered, and both sides were merged.

#### RESULTS

Figure 5 shows the average values of root volumes for each category of the tooth.

Table 1 compares for each tooth category, the anchorage values estimated by Jarabak and Fizzell<sup>[3]</sup> and the radicular volume found in this research as well as the proposed anchorage coefficient.

Jarabak attributed the smallest value for the mandibular central incisor taking this tooth as a reference (weakest tooth). Jarabak and Fizzell<sup>[3]</sup> values were based on root surface area and length.

Furthermore, root volume values allow us to assign new anchorage coefficients to each tooth [Figure 6].

The root volume of the mandibular central incisor found in this study [Figure 5] is in accordance with Jarabak estimation, and an anchorage coefficient of 1 is assigned to this tooth.

#### DISCUSSION

The aim of this study is to come up with new dental anchorage coefficients values based on radicular volume calculation using a high precision diagnostic tool such as the 3D scanner providing the clinician with an improved comprehensive view on the mechanics of tooth movement during orthodontic treatment.

In fact, SR (resistance to movement) of teeth remains the only anchorage mean when no reinforcement of anchorage is made (conventional or temporary anchorage devices [TADs]). Any tooth in the oral cavity is considered not to be in a fixed position.

Before the advent of microimplants or TADs, conventional mechanics using extraoral forces and/or intermaxillary traction was traditionally applied in orthodontics.<sup>[1]</sup>

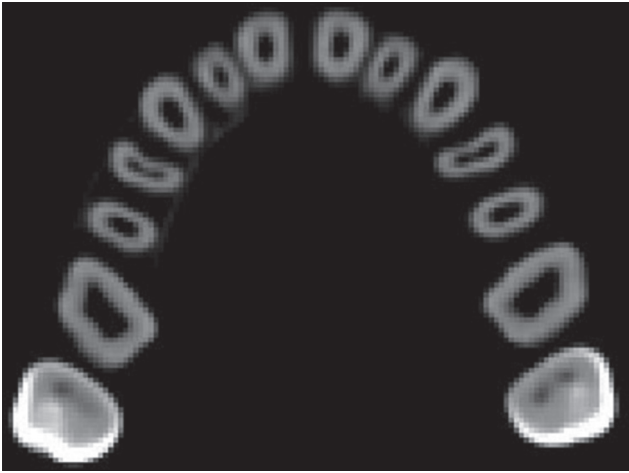


Figure 4: Axial cut showing the borderline between root and crown at the level of 17 and 27

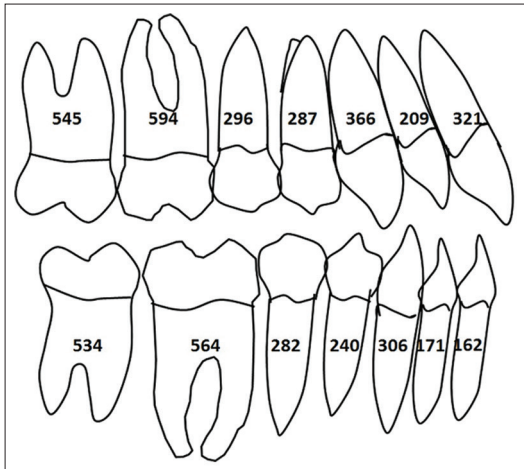


Figure 5: Mean values of root volumes for each type of tooth

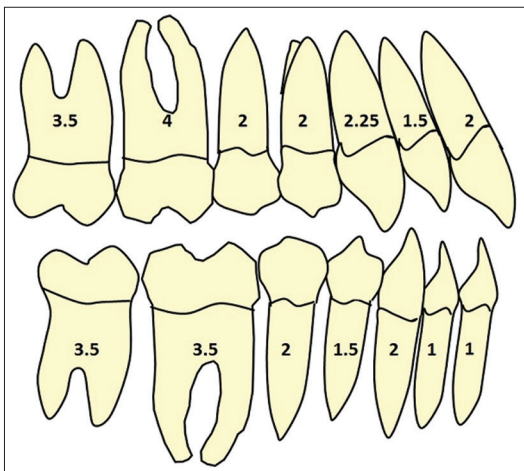


Figure 6: Anchorage coefficients of each category of tooth

MR (ability to movement) affects orthodontic mechanics with and without microimplants. In orthodontic treatment, MR involves the displacement of a tooth or a segment of teeth while relying on other teeth, i.e., SR.

Table 1: Average root volume, anchorage coefficients found in this study, and Jarabak's anchorage coefficients

Tooth category	Radicular volume in mm <sup>3</sup> found in this study	Anchorage coefficients found in this study	Jarabak anchorage coefficients
Maxilla			
UPP1	321	2	4
UPP2	209	1.5	3
UPP3	366	2.3	8
UPP4	287	2	7
UPP5	296	2	6
UPP6	594	4	9
UPP7	545	3.5	
Mandible			
LOW1	162	1	1
LOW2	171	1	2
LOW3	306	2	8
LOW4	240	1.5	5
LOW5	282	2	5
LOW6	564	3.5	10
LOW7	534	3.5	

The number which follows UPP and LOW corresponds to the number of the tooth; (UPP1 - tooth of upper central incisor right and left merged; 11 and 21). UPP=Upper tooth, right and left teeth merged, LOW=Lower tooth, right and left teeth merged

Table 2: Anchorage coefficients of different teeth segments

Teeth segments	Anchorage coefficient
Maxillary anterior segment (UPP1 and UPP2)	7
Mandibular anterior segment (LOW1 and LOW2)	4
Maxillary 6 anterior teeth (UPP1, UPP2, and UPP3)	12
Mandibular 6 anterior teeth (LOW1, LOW2, and LOW3)	8
Maxillary 2 first molars (UPP6)	8
Mandibular 2 first molars (LOW6)	7
Maxillary 4 molars (UPP6 and UPP7)	15
Mandibular 4 molars (LOW6 and LOW7)	14

The number which follows UPP and LOW corresponds to the number of the tooth; (UPP1 - tooth of upper central incisor right and left merged; 11 and 21). UPP=Upper tooth, right and left teeth merged, LOW=Lower tooth, right and left teeth merged

**ANCHORAGE COEFFICIENT OF EACH CATEGORY OF TOOTH**

The proposed anchorage coefficients given by Jarabak and Fizzell<sup>[3]</sup> and which was the only one stated in the literature was overestimated according to the present study [Table 1].

For example, in our results, the coefficient value for the maxillary canine was 2.25 and appears not to be similar to what has been reported by Jarabak and Fizzell<sup>[3]</sup> where the coefficient value was 8. This difference may be due to the high precision given by our tool compared to the simple estimation given by the other researcher.

This overestimation was also valid for all the categories of teeth.

### ANCHORAGE COEFFICIENT OF DIFFERENT TEETH SEGMENTS

Whereas the anchorage coefficient of different segments of teeth, to the best of our knowledge, it was not reported in the literature yet. Following our study results, it becomes easier to compare the anchorage coefficient of different teeth segments frequently used in different phases of the treatment [Table 2].

However, some orthodontics managements are considered as “dangerous,” and good care should be taken before initiating any procedure. The usage of extraoral forces or TADs is mandatory in these cases.

Finally, our study aiming to establish a new teeth anchorage coefficient values is not without limitations. Because of the limited number of scans examined due to our exclusion criteria, final conclusions must be postponed until future research validates our results.

Moreover, other forthcoming perspectives should be directed such as localizing in 3D the center of resistance of the whole dentition on both arches which is essential in tooth mechanics to obtain the most desirable movement in orthodontics and finding a more precise surface area measurement.

### CONCLUSION

Nowadays, recent evolution in dental imaging helps the orthodontist for a better understanding of general orthodontic principles.

The new anchorage coefficients found in this study helps facilitate orthodontic treatment by avoiding iatrogenic errors.

The authors recommend performing precise anchorage estimation before any orthodontic therapy.

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Nil.

### CONFLICTS OF INTEREST

There are no conflicts of interest.

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