Biology of the Alveolar Bone: Orthodontic Tissue Regeneration (OTR)

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Abstract: - Today the treatment of adult patients with complex dental problems often requires an interdisciplinary collaboration between different specialties of dental medicine among them frequently orthodontics: interdisciplinary orthodontics. The advancements in material science, biomechanics and in understanding the biology of the alveolar bone led to improved treatments of cases that once seem to be hopeless. The orthodontist, the surgeon and the periodontist work on the same biological substrate: the alveolar bone. Lack of alveolar bone support is probably the most common and challenging dilemma confronting this interdisciplinary team. The paper will discuss and evaluate periodontal lesions like bone dehiscence or fenestration, age-related changes of the bone, the lag time, special biomechanical considerations and the effect of intrusion and extrusion of teeth in patients with periodontal disease. The orthodontic tooth movement, even in vertical or horizontal plane, has a great osteogenic potential. The positive influence of orthodontic tissue regeneration (OTR) on the depth and the breadth of the alveolar bone will be highlighted in various clinical cases. In conclusion interdisciplinary orthodontics can contribute significantly to overcome challenging bone defects in adult patients, joining the new regenerative paradigm of modern dental medicine.

Key-Words: - interdisciplinary adult orthodontics, bone dehiscence, bone fenestration, bone remodeling, lag time, orthodontic extrusion, premolar distalization, osteogenic potential, regenerative paradigm

1 Introduction

Orthodontic treatment of adults because of the association of primary and secondary dento-maxillary malocclusions with various diseases of the stomatognathic system often requires an interdisciplinary collaboration between Orthodontics, Periodontics, Implantology, Maxillofacial Surgery and Prosthodontics [1].

Adult teeth have an altered morphology with fillings, abrasion facets and changes of periodontium and therefore the treatment objectives are frequently compromise solutions. Compromise can be controlled only with a vast amount of information. This can be obtained only through this interdisciplinary approach in which there is a permanent interaction between the disciplines and each discipline enhances the capability of the other [2].

By respecting protocols and interdisciplinary collaboration rigors many cases that initially seem to be compromised could reach a functional and aesthetic balance (Fig.1)

![Fig.1 Periodontally compromised adult patient with secondary dento-maxillary malocclusions before (left) and after (right) the interdisciplinary orthodontic treatment](image)

The orthodontist, the surgeon and the periodontist work on the same biological substrate: the alveolar bone. Lack of alveolar bone support is probably the most common and challenging dilemma confronting this interdisciplinary team.

The alveolar bone biology and the osteogenic potential of orthodontic tooth movement (OTM) are one
of the most fascinating debates in the field. Each dentist involved in this team should thoroughly understand the biological factors and principles behind OTM.

To have good results in such complicated cases it is very important to have those diagnostic tools that facilitate an easy communication between the different specialists and with the patients for weighing the risks and benefits of all treatment options. Today the evolution of the digital technology has changed computers from having a limited, supporting role mainly in managing databases to one being indispensable in orthodontic treatment [3, 4, and 5].

When we refer to orthodontic tissue regeneration (OTR) we must take into consideration two directions:

- Regeneration of the alveolar bone that is affected by periodontal disease or extraction (atrophic extraction sites) with the help of orthodontic tooth movement (OTM).
- Regeneration of the alveolar bone (affected in the active treatment) during the retention phase of the orthodontic treatment.

2 Problem Formulation

Different from traditional orthodontics and dento-facial orthopedics that is performed on growing bones interdisciplinary orthodontics is done on an adult alveolar bone that has some age-related changes. There is an involutive ageing process of the periodontal structures and different degrees of alveolar bone loss. The amount of trabecular and cortical bone decreases, the cortex is more porous and the normal decrease in bone volume is often accentuated by periodontal disease or premature extraction of teeth.

This periodontal involution increases the risk of bone dehiscences, fenestrations and root resorption (Fig.2) [6].

The clinical outcome of extensive bone dehiscence is loss of anchorage and a predisposition to the development of gingival recession [6].

The objective of this study was to evaluate the different applications of orthodontic tooth movement on the biology of the alveolar bone and to highlight the positive influence on the bone morphology.

3 Problem Solution

Today the modern digital 3D technology like Cone-Beam Computed Tomography (CBCT) allow three-dimensional quantification of the alveolar bone, identifying of periodontal lesions and a true tooth/bone relation, at scale, without overlying structures (Fig.3).

With the CBCT we can evaluate, in all dimensions, the amount and distribution of bone deposits occurring around the teeth, before and after the treatment.

One of the most frequently situation in our population is the premature loss of the first molar. Typically the second molar tips forward, the upper molar extrudes and the premolars distalize (Fig.4).

What happens in this situation with the alveolar bone? In a radiological study we concluded that angular bone loss from the mesial face of the tilted molar appears to be rather an adaptation of the alveolar bone at the position of the second molar, a local anatomical
variation than a true periodontal pocket developed in this area (Fig.5) [8].

Fig. 5 In 64.70 % of the skulls there was a parallelism between the enamel-cementum junction and the alveolar bone margins

The orthodontic molar uprighting, one of the most common orthodontic procedures done as an aid to restorative therapy will improve the local alveolar morphology and the periodontal health (Fig.6).

Fig. 6 Clinical and radiological aspects of molar uprighting

At patients with agenesis or previous extractions of permanent teeth (frequent) the alveolar bone is atrophic with reduced height and labiolingual thickness. In this situations when you move orthodontically a tooth (generally a premolar) through the alveolus new bone will build up the alveolar process (Fig.7).

Fig. 7 Distal movement of a premolar creates a wide area of new alveolar bone

With slow tooth movement, the periosteum on the labial and lingual surfaces of the alveolus may form bone as teeth are moved into the edentulous site [9]. One of the greatest specialists in this domain, prof. Birte Melsen mentioned: “When I want to move a tooth through an edentulous area it is important to avoid tipping the tooth into the region; the roots should, in principal, be moved ahead of the crown. This builds up bone by exerting a slight pressure, thereby increasing the density of the bone ahead of the tooth” [10].

When teeth have to be moved into areas with an atrophic alveolar process due to extraction of teeth, a balance between resorption and apposition has to be kept, and the tooth is, so to speak, “carrying its alveolus along” [10].

From biomechanical point of view the apical displacement of the center of resistance (according to the marginal bone level) requires use of low and well-controlled forces. The increase in the root-crown ration imposes application of modified moments or placement of the brackets more gingival.

As previously stated the base of the bracket is generally designed to be placed in the center of the vestibular crown. The manufactures should design a new base, more adapted to the gingival part of the crown in order to have a more stable tooth/bracket interface and introduce new information in the bracket (tip, torque, angulations) [11].

Fig. 8 Implant site development between two lower premolars after extraction of a temporary canine and moving the permanent canine in class I relationship

Also in horizontal plane orthodontic tooth movement can contribute to an implant site development by generating a surprisingly wide bony ridge. This is an important, biologic alternative to bone grafting or other periodontal procedures associated with the insertion of single implants (Fig.8).
When we use the orthodontic tooth movement to regenerate alveolar bone we must always take into consideration the lag time when we are planning the retention, because the lag time increases with increasing age (Fig. 9) [12].

Fig. 9 The lag time (the time between the formation of osteoid to the formation of mineralizing bone) on successive radiographies made at an interval of 8 month

The CBCT is very useful for the three-dimensional quantification of the alveolar bone for Orthodontics, Periodontics or Implantology. The Galileos software for virtual implant planning enables the precise positioning of the implant (Fig. 9).

Fig. 9 The implant site (a failure of interdisciplinary collaboration without using the OTM for OTR) was evaluated by CBCT and the software for three-dimensional pre-surgical dental implant treatment planning

Also in vertical dimension the orthodontic tooth movement has a great osteogenic potential. For example at patients with periodontal disease and vertical alveolar defects the orthodontic extrusion fills the vertical defect with newly formed alveolar bone (Fig. 10).

The orthodontic extrusion does not create a new attachment; it merely relocates the existing attachment in a coronal direction. The relationship between the cementoenamel junction and the bone crest is maintained; in other words, the bone follows the tooth [13].

This therapeutically possibility is used for development of implant sites by extrusion of teeth with poor prognosis and vertical bone defects. After the orthodontic extrusion the tooth is extracted and an implant is placed in this newly developed bone.

Tooth movements build up bone, whereas implants need bone [10].

Fig. 10 After extrusion of the left mandibular premolars that initially (left) have wide vertical bone defects around the apex new bone was formed around the teeth (right)

Sometimes in patients with periodontal disease and elongated teeth you have to intrude them. As a rule we can intrude when we have horizontal bone loss and regain some lost attachment [10].

We have to think at the osteogenic potential also during regular orthodontic therapy. Many times in the effort to compensate the alveolar discrepancies we perform “camouflage therapy” and we bring the teeth to the outer limit of the bone.

Dehiscences or fenestrations can be produced in the buccal alveolar plate by moving teeth in a facial direction but the bone will reform when the teeth are moved back to their original positions. It was also demonstrated that such movements are not necessarily accompanied by loss of connective tissue attachment [14].

The modern digital radiology allows us to observe the evolution of the alveolar bone around the tooth during the orthodontic treatment and in the retention period.

Recent studies have demonstrated that orthodontically induced bone dehiscences were partly repaired by osteoblastic periodontal remodeling in the retention period [6].

It is very important to have a good gingival biotype in order to have that osteoblastic repairing activity. In patients with thin gingiva and bone it is advisable to perform mucogingival surgery with free gingival graft for augmentation of the attached gingival tissues.

4 Conclusion

The remodeling of the alveolar bone during orthodontic treatments is a reality and orthodontic tissue regeneration (OTR) is a useful method in many clinical situations where we have to deal with an insufficient
alveolar bone. This technique requires sound knowledge of biology of the alveolar bone, a special biomechanics but most importantly a perfect collaboration between the members of the team.

The orthodontist as a tissue engineer (Bjorn Zachrisson) and interdisciplinary orthodontics can contribute significantly to overcome challenging bone defects in adult patients, joining the new regenerative paradigm of modern dental medicine.

References: