Orthodontic Extrusion of Traumatically Intruded Upper Central Incisor

Introduction
The incidence of traumatic dental injuries varies with age and has a high prevalence worldwide. [1] In most cases, the front teeth are the most affected, with the central incisors being at the highest risk of dental trauma. [2] [3] The maxillary arch is involved in a higher percentage (95.72%) of incidents when compared to the mandibular arch. [4]

Intrusion luxation can be defined as the form of traumatic dental injury that leads to tooth displacement deep into the alveolar bone. This usually results in severe complications (pulp necrosis, inflammatory root resorption, ankylosis); for this reason it is classified as a severe form of traumatic dental injury. [5] [6] Management of traumatically intruded anterior teeth is of prime importance, since these teeth are so important both aesthetically and functionally. Management of these traumatised teeth differs according to the root apex maturity and the severity of the intrusion luxation itself. Pulp necrosis occurs in one hundred percent of cases involving intrusion luxation of mature permanent teeth with fully-formed apex and in 62.5% of those involving intruded teeth with open apex. [7] [8] This case report aims to emphasise the importance of immediate orthodontic loading of traumatically intruded mature permanent teeth with closed root apex.

Diagnosis and Etiology
A 15-year-old female was referred to the orthodontic clinic for dental evaluation. Her chief complaint was, "I have a displaced upper front tooth following a sport accident." (Figure 1) During orthodontic evaluation, the patient reported that she had received a sport injury one day ago. An emergency treatment, she received immediate therapy by a general dentist, consisting of bleeding control, prescription of an antibiotic and an anti-inflammatory analgesic. Clinically, "The patient presented a dolichofacial pattern and normal occlusion, with well-aligned teeth, except for the traumatised upper left central incisor (4 mm intrusion depth) (Figures 1 and 2). Symptoms of temporomandibular disorders were not found. Pulp vitality of the traumatised tooth was tested with ethyl chloride, and a negative result indicated the presence of necrotic pulp tissue."

Treatment Objectives
The patient had an intruded upper left central incisor tooth as a result of a traumatic accident, so the following treatment objectives were established:
1. Extrude the intruded upper left central incisor into its original physiologic position
2. Allow easy access for necrotic pulp extirpation from the intruded incisor.

Treatment Plan
The treatment plan should aim to extrude the intruded tooth back into its original physiologic position within the upper arch. Three treatment alternatives were available:
1. Giving the tooth its own chance to re-erupt spontaneously
2. Surgical repositioning for the intruded tooth
3. Orthodontic extrusion.

The authors preferred the third treatment option, so the treatment plan was to orthodontically extrude the traumatically intruded upper left central incisor as soon as possible following the traumatic injury. Additionally, endodontic treatment was also planned in order to extirpate the necrotic pulp (the tooth had complete root development), thus minimising the chances of external root resorption and tooth loss.

During the first week of treatment, the patient was instructed to follow a soft diet, with the aim of avoiding any traumatic contact with the traumatised tooth. Three weeks following the start of the alignment phase, the tooth was extruded enough (close to the level of the other central incisor) to allow easy access for necrotic pulp extirpation (ethyl chloride examination confirmed the necrotic pulp status).
The necrotic pulp was extruded two weeks following the start of orthodontic treatment and a non-setting calcium hydroxide root canal filling material was placed for about three weeks. The aim of using the calcium hydroxide-dressing material was to dissolve any pulp remnants, and to alkalise the environment to minimise the inflammatory root resorption [9].

Then 0.014 and 0.016 inch NiTi wires (Ortho Technology Company) were used, in order to complete the alignment phase by moving the traumatised tooth back into its normal and physiological position. The alignment phase took about three months, after which the tooth was normally positioned within the line of the arch. (Figure 4, 4-d)

The result was maintained with an upper fixed lingual retainer (Ortho Technology) extending from upper right canine to upper left canine. (Figure 5, 6)

By the end of the treatment, the gingival margin of the affected tooth was not level with the central incisor (Figure 4-A). This may be the result of the rapid extrusive forces which were applied to the intruded tooth. A gingivectomy for the upper left central incisor was performed about one year later in order to level it with the gingival margin of the right central incisor. (Figure 7, 7-B)

Discussion

Traumatic intrusion luxation is a serious type of injury, and it occurs most frequently in upper incisors. [4] Management of traumatically intruded permanent teeth differs according to the root apex maturity and the severity of the luxation injury itself. In case of root intrusion of teeth with incomplete root formation, the intruded teeth are given the chance to re-erupt spontaneously within three weeks, [10] [11] [12] if the intruded tooth does not erupt by itself during the three week observation period, it is preferable to extrude the tooth, in order to replace it in the line of the arch.

In our case, spontaneous re-eruption was not preferred because, according to the UK national clinical guidelines, the chances of spontaneous re-eruption in mature teeth are low, especially if the intrusion is above 3 mm and, if eruption occurs, the tooth will not reach up to the pre-injury occlusal level [13] [15].

As a result, the authors preferred immediate orthodontic extrusion, aiming to maintain the chance of ankylosis. This concurs with Andreasen, who states that orthodontic forces should be applied within the first few days following the intrusive luxation injury [14]. The initial arch wire was thin with low force to minimise any heavy and non-physiologic loading on the luxated tooth.

Endodontic treatment was mandatory in our case, since the intruded tooth had a fully-formed root with completely closed apex. [7] The pulp was extruded to avoid the development of external root resorption, which can lead to tooth loss [15]. Surgical repositioning was not preferred because it usually produces severe trauma to the periodontal ligament, leading to replacement resorption and tooth loss [16].

Conclusion

The application of immediate orthodontic extrusion forces to reposition the traumatically intruded upper left permanent central incisor was effective. Early tooth repositioning created easy access for pulp extrapulpalisation which probably minimised the chances of external root resorption, ankylosis and hence tooth loss.

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A Practical Treatment Objective: Alveolar Bone Modeling with a Fixed, Continuous-Arch Appliance

By Thomas W. Bannor & Frank Bogdan, USA

Bone is a dynamic tissue that is continuously adapting its structure via the processes of remodeling and modeling. Remodeling is the coupled sequence of resorption and formation involving in physiologic turnover. It is necessary to adjust internal architecture in response to mechanical needs, repair microdamages in the bone matrix, and to maintain plasma calcium homeostasis. Remodeling can only be observed histologically or by chemical assay of biomarkers. Modeling is a change in the size and shape of a bone that can be observed and measured radiographically. It is the net gross anatomic result of bone resorption and formation on a given bone surface in response to growth and development or mechanical load. These processes are well accepted phenomena in the field of physiology.

In the orthodontic literature, it is widely held that the alveolar bones of the maxilla and mandible are immutable—that once formed, their size and shape cannot be changed significantly with tooth-borne, continuous-arch orthodontic appliances. Attempts to do so have been associated with root and cortical plate resorption, loss of periodontal attachment and unstable tipping of teeth. Under this paradigm, orthodontic treatment must maintain the existing size and shape of the alveolar bone. Many times, this can only be accomplished with surgery, tooth extraction, or separation of the midpalatal suture.

In recent years, there has been a growing body of clinical evidence bolstered by studies that challenge the immutability of the alveolar bone and the mandible to treat the existing dentoalveolar arch form. The purpose of this article is to present a review of the literature challenging alveolar bone immutability along with clinical cases treated with passive self-ligating orthodontic brackets and low friction/know protocols that demonstrate alveolar bone modeling.

Challenging Alveolar Bone Immutability

The alveolar process is defined as that part of the maxilla and mandible that forms and supports the sockets of the teeth (Fig. 1). It includes the thin laminae of bone that surrounds the root of the tooth and gives attachment to the principal fibers of the periodontal ligament.

It also includes the supporting inner and outer cortical plates of compact bone along with the spongiosa bone between the cortical plates (Fig. 2). Historically, no distinct boundary exists between the body of the maxilla or the mandible and their respective alveolar processes, the bone surrounding the teeth from root apex to the crest of the socket is considered to be the alveolar bone.

By means of the teeth, alveolar bone can be loaded with biomechanical force. The cellular response of the PDL to orthodontic force has been well characterized on both the pressure and tension sides of the bony socket surrounding the root of the teeth and its periodontal ligament are translated through the trough of bone confined by the buccal and lingual cortical plates. Until recently, modeling—or changing the size and shape of the developed alveolus by translating the cortical plate—was not deemed possible with fixed orthodontic appliances, and consequently, has not undergone rigorous study. The critical questions that must be answered to challenge alveolar bone immutability and foster an acceptance of treatment modalities that are not confined to the existing size and shape of the alveolus are:

1. Is the alveolus, confined by the buccal and lingual cortical plates immutable or is there evidence that it can undergo modeling?
2. If it can undergo modeling, under what conditions can it occur?
3. Can fixed, continuous-orthodontic appliances induce alveolar bone modeling?
4. Is there a cellular mechanism of action that can explain orthodontically induced alveolar bone modeling?

Mypo-Peristaltic Induction of Alveolar Bone Modeling

Dr. Rolf Frankel described the transverse arch modeling observed in periodontal patients treated with his Function Regulator Appliance (Fig. 3). He reported that the increase in the transverse dimension observed in these patients is achieved primarily through the action of the buccal shifts on the apex. The alveolar shields disrupt the equilibrium of forces acting on the dentoalveolus by removing the pressure of the buccal musculature and allowing the continuous force of the tongue to dominate. According to Frankel, when the forces of the cheeks are eliminated, the teeth tip laterally in the direction of least resistance. The alveolar walls in the radicular area are likewise deformed in a buccal direction.

Furthermore, the acrylic shields extending into the vestibule exert a constant outward pull on the connective tissue fibers and muscle attachments that is transmitted to the alveolar bone by the fibers of the periodontium. Apposition of buccal bone aids in the lateral movement of the dentoalveolus. The ability of periodontal tension to induce apposition of bone on the lateral alveolus has been demonstrated in the animal studies of Altmann and Harvold. In addition, a study by Breiden, et al, utilizing metallic implants placed in the maxilla of patients treated with the Frankel appliance demonstrated that widening of the maxilla was due to deposition of new bone along the lateral border of the alveolus rather than increased growth at the midpalatal suture.

This phenomenon of alveolar modeling, specifically lateral translation of the alveolus, is achieved by disrupting the equilibrium of the inner and outer cortical musculature and peridental tension is consistent with the Functional Matrix Theory of Moss. While granting the innate growth potential of cartilage and bone, his theory holds that growth of the face occurs as a response to functional needs and neuromuscular influences and is mediated by the soft tissue in which the jaws are embedded. The theory, simply stated, is that bones do not grow but are grown, emphasizing the osteogenic primary of function over form. The Frankel appliance achieves a change in form by changing the function of the matrix tissues of the dentoalveolus.

Load-Induced Alveolar Bone Modeling

It is commonly observed in the field of dental medicine that the continuous load of a growing odontogenic cyst can significantly model the alveolar bone of the maxilla and mandible, causing remarkable displacement of the cortical bone. This pathologic process is well-established and has been extensively documented in case reports and textbooks. The interstitial pressure of various odontogenic cysts has been measured and found to exert an ultra-low force load on the alveolar bone. This phenomenon clearly demonstrates that the deroofed alveolus can be modeled via pathologic induction with light, continuous force. Another commonly observed example of
bone modeling is the bulge of the cortical plate associated with a pala-
tally impacted canine. The impacted tooth is typically associated with an
enlarged follicle. When the canine is exposed and brought into the center of
the alveolus, a normal palatal con-
tour returns.

Kokich and Kokich25 demonstrated
localization modeling of the adult al-
veolus in response to tooth displace-
ment. Light, continuous orthodontic
force was employed to displace a tooth into the atrophic alveolar ridge
associated with a congenitally ab-
sent second premolar. The dislocated
tooth moved with its supporting
bone, changing the size and shape of the
atrophic alveolus (Fig. 3).

Fontenelle reported alveolar bone
modeling with a passive/active dis-
sociation appliance in non-growing
patients.26 The appliance (Fig. 4) con-
sisted of a passive, rigid-cast lingual
arch and active, low-modulus wires
activated between the cast lingual
arches. Dissociation of the passive
and active components facilitates
the application of low, constant-force
load with near constant moment-to-
force ratios, resulting in bone mod-
ing induced by dental displa-
acement. Clinical cases were shown
demonstrating lateral modeling of the
alveolus as observed by Frankel and
localized alveolar modeling with
tooth displacement as observed by
Kokich and Kokich.

Williams and Murphy described al-
veolar bone modeling with evidence
of apposition of bone on the maxi-
dary buccal alveolus in permanent
dentine patients (Fig. 5a-c). This
was induced by a light, continuous
load applied bilaterally to the max-
dary alveolus with the Max 2000®
alveolar development appliance (Fig.
5a). Their appliance consists of two
nickel-titanium springs embedded
in and connecting separate acrylic
panels in a framework retained by
springs activated one-half-of:
abutment length between the man-
dibular permanent central incisors
and primary canines, and between
the maxillary left permanent lat-
eral incisor and primary first molar.
Low-torque brackets were selected
for the upper and lower incisors to
help maximize proclination from
the force of the spring. Damon wire
sequence protocols were observed.

Result
Pre- and posttreatment images dem-
strate the treatment result after 16
months of treatment. The size-cor-
corrected view of the mandibular arch
illustrates the significant change in
the size and shape of the mandibular
alveolar bone induced by this ap-
proach. Similar changes were seen in
the maxilla as well. The patient’s
parents were pleased with the result of
Phase I treatment and opted not to
pursue Phase II finishing treatment.

CHILD ALVEOLAR MODELING:
After Eruption of Permanent Teeth. Phase II Treatment was Not Pursued in this Case

CHILD ALVEOLAR MODELING:
Pre-/Posttreatment Comparison Demonstrates Alveolar Bone Modeling

PRESUMPTION

POSTTREATMENT

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CASE STUDY 2

PERIADOLESCENT ALVEOLAR MODELING: Pretreatment

Diagnosis
An 11-year-old female patient presented with a Class I malocclusion and severe tooth size/arch length discrepancies with 9 mm of crowding in the maxillary arch and 15 mm of crowding in the mandibular arch. Her mandibular incisors were upright at 89° to the mandibular plane and she exhibited normal circumoral muscle tonus and competent lips. Her parents wanted to attempt a nonextraction treatment plan. Informed consent was obtained and a therapeutic diagnosis was initiated with a reassessment planned for approximately 6 to 9 months to determine if the nonextraction attempt could continue or if extraction would be required.

Treatment Summary
Damon protocols were employed with initial .014” Copper Ni-Ti wires and NiTi open-coil springs activated one half of a bracket width to begin to create space for the unbracketed, blocked-out teeth. Eyebolt attachments were placed on the lingually blocked-out teeth and lightly ligated to the coil springs with enough force to minimally deflect the archwire. Since the alignment at the 10-week appointment was deemed insufficient to ensure a larger wire and comfortably close the bracket door, the initial wires were inspected for deformation and replaced. The springs were then reactivated, the blocked teeth religated and the patient reappointed for 8 weeks.

Although in significantly crowded cases the transitional wire is typically a .016” Copper Ni-Ti wire engaged in preparation for a .018” x .025” Copper Ni-Ti wire, at the fifth week bracket alignment was again deemed insufficient for rectangular wire engagement so a .018” Copper Ni-Ti wire was placed, the springs were reactivated and the blocked-out teeth religated. At subsequent appointments as space was created, initially blocked-out teeth were bracketed and engaged with .014” Copper Ni-Ti wires. At 8.5 months, the decision was made to continue with the nonextraction treatment plan. This severely crowded case did not progress beyond the .016” Copper Ni-Ti wires until 12 months into treatment.

Results
The final result was obtained after 23 months of treatment. Retention included bonded lingual wire retainers and clear, vacuum-formed Essix-style removable retainers to be worn while sleeping. Size-corrected lower occlusal photographs taken at initial bonding and debonding illustrate the change in the size and shape of the mandibular alveolus induced by passive self-ligation treatment. By the three-year posttreatment follow-up appointment, teeth #8 and #9 had been crowned and the bonded maxillary lingual wire had been removed. The patient reported infrequent removable retainer wear and the alveolar modeling obtained had remained remarkably stable.

PERIADOLESCENT ALVEOLAR MODELING: Pretreatment

PRETREATMENT

POSTTREATMENT

3 YEARS POSTTREATMENT

CASE STUDY 3

ADOLESCENT ALVEOLAR MODELING

Diagnosis
A female patient age 13 years, 5 months presented with a Class I malocclusion, crowding and constricted dental arches. Her case illustrates how muscular imbalance can have a constraining impact on the development of dental arch form. The collapsed buccal segments and retroclined mandibular segments and retroclined mandibular incisors are indicative of the influence of hypertonic buccinator and orbicularis oris muscles.

Treatment Summary
The key element in cases like this are the leveling sequence and the use of turbos for disarticulation. It is essential to stay in round wires at least 6 months to give the muscles adequate time to rebalance; that is, to change the balance of forces between the overpowered tongue muscle versus the muscles of the lips and cheeks. With passive self-ligation, muscles become an ally in treatment similar to the way the Frankel assists transverse development. The wire sequence in this case (both arches) was .014” x .025” and .016” (6.5 months) Copper Ni-Ti followed by .018” x .025” and .019” x .025” TMA (lower) and .017” x .025” TMA (upper).

Results
The case result was obtained in 19 months. The light, biomechanical load transmitted to the mandibular bone with a fixed PSL appliance combined with small diameter, low-modulus-of-elasticity archwires demonstrates alveolar bone modeling as the teeth uprighted in the transverse dimension similar of the patient’s mandibular arch.
PERIADOLESCENT ALVEOLAR MODELING: Results

ADOLESCENT ALVEOLAR MODELING: Pre-/Posttreatment Comparison Demonstrates Esthetic Benefit of Transverse Alveolar Bone Modeling

Note: The mandibular canines in the patient’s retention records seem to indicate significant expansion but is explained by the uprighting of these teeth over their apices.

CASE STUDY 4
ADULT ALVEOLAR MODELING: Pretreatment

Diagnosis
A 21-year-old female patient presented with an anterior open bite and bilateral, posterior cross bites. Her dental history included Phase I expansion and Phase II comprehensive treatment with another orthodontist. She was referred by an oral surgeon for orthodontic alignment prior to orthognathic surgery to correct the open bite and constricted maxilla.

Treatment Summary
Treatment was initiated using PSL appliances and low friction/low force protocols with 2 oz posterior cross elastics engaged bilaterally from attachments on the lingual surfaces of the maxillary second premolars and first molars to buccal attachments on the mandibular second premolars and first molars. The occlusion was disarticulated with flat-plane composite build-ups on the occlusal surfaces of the maxillary first and second molars. When the case progressed to the .019” x .025” stainless steel wires, the maxillary arch was sectioned bilaterally between the lateral incisors and canines in preparation for surgery. The surgeon, however, deemed that orthognathic surgery was no longer required. The case was finished with vertical elastics and retained with bonded lingual retainers and a Damon splint retainer prescribed for nightly wear for the initial 12 months of retention.

Results
Treatment was completed in 21 months. Size-corrected upper occlusal photographs taken at bonding and debonding illustrate the change in the size and shape of the maxillary alveolus induced by passive self-ligation treatment. Unfortunately, the patient relocated and was unavailable for long-term follow up.

PERIADOLESCENT ALVEOLAR MODELING: Results

ADULT ALVEOLAR MODELING: Pre-/Posttreatment Comparison Demonstrates Alveolar Modeling. Surgery was Precluded in this Case.
Discussion
The case reports presented demonstrate examples of the change in the size and shape of the maxillary and mandibular alveolar bone observed in adolescent, adult, and children treated with a passive self-ligating, continuousarch appliance and Damon low-friction/low-force treatment protocols. Specifically, the increase in the transverse dimension of the alveolus appears to be the result of lateral translation of the buccal and lingual cortical plates induced by the biomechanical load applied to the teeth and transmitted to the alveolar bone. These cases provide additional clinical evidence for the ability of the alveolar bone to undergo biomechanical load-induced remodeling.

As Frankel had done previously with his Function Regulator appliance, Damon has proposed a mechanism of action for the direct/indirect response to his treatment regimen. Based on clinical observations and analysis of photographs, plaster study model measurements and medical CT surveys of treated cases, he suggested that the light, continuous force delivered by his treatment approach disrupts the equilibrium of the tooth positions maintained by the inner and outer oral musculature acting on the alveolus and dentition. When the anterior component of the force acting along the continuous archwire is kept low, it is mitigated by the resting pressure of the lip in patients with adequate circumoral muscle tonus. The posterior component of force is likewise resisted by multiple rooted molars along with the ascending ramius in the mandible and the tuberosity in the maxilla. A resultant lateral component of force is expressed and transmitted from the teeth to the alveolar bone, inducing bone modeling or posterior arch adaptation as he describes it.

The OSIM findings of Badawi support Damon's proposed mechanism of action, specifically the assertion of a lower anterior vector of force delivered with a passive self-ligating appliance compared with an elastomeric-ligated appliance applied to the same simulated malocclusion. In addition, there is a cellular mechanism of action that supports alveolar bone modeling induced by tooth displacement. Figure 8 from Graber describes bone modeling occurring in the periodontal ligament and on the periosteal surfaces resulting from net apposition of bone in the direction of the line of applied force and net resorption of bone away from the direction of force. Furthermore, this ability to move bone with a light, continuous load applied to the teeth has been corroborated in the sagittal dimension by Melsen and Alsalim.

Despite the evidence presented in this article, there remains considerable debate regarding the immutability of the alveolar bone and the treatment response to low-friction/low-force passive self-ligating appliances. Rigorous investigation should be undertaken to validate and understand these clinical observations. Future clinical investigations should incorporate case selection criteria that include subjects with adequate circumoral muscle tonus as well as close adherence to the established treatment protocols as described in the case reports above.

In addition, future CRCT analysis should consider the voxel size and resolution of the machines used in making alveolar bone determinations as well as the time period in which the posttreatment assessments are undertaken to allow adequate time for completion of secondary mineralization.

Conclusions
This article presents case reports demonstrating a change in the size and shape of the alveolar bone in child, adolescent and adult patients treated with a continuous arch, self-ligating appliance. These cases, along with a growing body of evidence, challenge the immutability of the alveolar bone and the axiom of treating to the existing arch form. It is the authors' considered opinion that Melvin Moss's Functional Matrix Theory is correct and the change in alveolar form induced by this low-friction, low-force treatment approach provides an opportunity to recapture the full genetic potential of the patient's alveolus.

Furthermore, alveolar bone modeling is a practical treatment objective that can decrease the need for more invasive approaches in appropriately selected and appropriately treated patients.

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References are available from the publisher.


Figure 8. Orthodontic bone modeling, or site-specific formation and resorption, occurs along the periodontal ligament and periosteal surfaces. Illustration from Orthodontics: Current Principles and Techniques, Graber, Universal & Vig, 4th edition. Reprinted by permission.
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