Orthodontic Extrusion of Traumatically Intruded Upper Central Incisor

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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. As 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 physiological position
2. Allow easy access for necrotic pulp extirpation from the intruded incisor

Additionally, endodontic treatment was also planned in order to extricate the necrotic pulp (the tooth had complete root development), thus minimising the chances of external root resorption and tooth loss.

Treatment Plan

The treatment plan should aim to extrude the intruded tooth back into its original physiological 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 planned in order to extricate the necrotic pulp (the tooth had complete root development), thus minimising the chances of external root resorption and tooth loss.

Treatment Progress

Two days after the traumatic injury, the authors were able to bond the upper teeth with a fixed orthodontic appliance extending from the upper right 1st permanent molar to the upper left 1st permanent molar. A 0.022-in slot / Roth prescription pre-adjusted brackets (Pinnacle-Ortho Technology) were used with a 0.012 inch NiTi orthodontic wire (Ortho Technology company) as an initial aligning arch wire (Figure 3).

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).

Figure 1

Figure 2
months, after which the tooth was normally positioned within the line of the arch. (Figure 3, 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 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, 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 mild 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 re-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 re-eruption occurs, the tooth will not reach up to the permanent 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 minimize any heavy and non-physiologic loading on the intruded 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 extripated, to avoid the development of external root resorption, which can lead to tooth loss. [5] 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 extrusive forces to reposition the traumatically intruded upper left permanent central incisor was effective. Early tooth repositioning created easy access for pulp extraposition which probably minimized the chances of external root resorption, ankylosis and hence tooth loss.

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**References**


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

By Thomas W. Barnon & 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 osteoclastic and osteoblastic formation and involvement 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 growth 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 change significantly with tooth-borne, continuous-arch orthodontic appliances. Attempts 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. In many cases, this can only be accomplished with surgery, tooth extraction, or separation of the midpalatal suture.

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 dentofacial 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/low-force 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. It includes the thin lamellae 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 between the cortical plates. Though anatomically, no distinct boundary exists between the body of the maxilla or 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 bone socket surrounding the root of the tooth 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 alveolar bone 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-arch orthodontic appliances induce alveolar bone modeling?
4. Is there a cellular mechanism of action that can explain orthodontically induced alveolar bone modeling?

Myo-Periosteal Induction of Alveolar Bone Modeling

Dr. Rolf Frankel described the transverse alveolar bone remodeling observed in periosteal patients treated with his Function Regulator Appliance (Fig. 2) [1] [2] [3]. He reported that the increase in the transverse dimension observed in these patients is achieved primarily through the action of the buccal shields on the appliance. The buccal shields disrupt the equilibrium of forces acting on the dentoskeleton by removing the pressure of the buccal musculature and allowing the light 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 wall 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 are transmitted to the alveolar bone by the fibers of the periosteum. Apposition of buccal bone aids in the lateral movement of the dentoskeleton. The ability of periosteal tension to induce apposition of bone on the lateral alveolus has been demonstrated in the animal studies of Altmann [4] and Harvold [5] [6] [7]. In addition, a study by Breiden et al. [8] utilizing metallic implants placed in the maxillae 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, can be achieved by disrupting the equilibrium of the inner and outer cortical lamellae and periosteal tension is consistent with the Functional Matrix Theory of Moser [5] [6] [7]. 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 modulated 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 ontogenetic priority of function over form. The Frankel appliance achieves a change in form by changing the function of the matrix tissues of the alveolar musculature.

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 have been measured and found to exert an ultra-low force load on the alveolar bone. This phenomenon clearly demonstrates that the developed 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 palatal 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 contour returns.

Kokich and Kokich demonstrated localized modeling of the adult alveolus in response to tooth displacement. Light, continuous orthodontic force was employed to distalize a tooth into the atrophic alveolar ridge associated with a congenitally absent second premolar. The distalized tooth moved with its supporting bone, changing the size and shape of the atrophic alveolus (Fig. 3).

Posteriore reported alveolar bone modeling with a passive/active dissociation appliance in non-growing patients. The appliance (Fig. 4) consisted 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 modeling induced by dental displacement. 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 alveolar bone modeling with evidence of opposition of bone on the maxillary buccal alveolus in permanent dentition patients (Fig. 5a,b). This was induced by a light, continuous load applied bilaterally to the maxillary 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 bands on the first bicuspids and first molars. The transpalatal springs delivered 150 grams of force each to a lateral direction. Biopsies were performed on two patients upon completion of lateral alveolar development. The specimens were harvested via full-thickness flaps from the labial alveolar crest between the maxillary right first bicuspid and canine (Fig. 5b). An internal control specimen was taken from interpulpal bone between the ipsilateral mandibular first bicuspid and canine (Fig. 5c). Standard hematoxylin and eosin stained sections were examined with and without polarized light and a maxillary specimen was subjected to fractal analysis.

The maxillary treatment sections demonstrated the absence of the lamellar pattern characteristic of mature bone and polarized light demonstrated a woven bone pattern characteristic of immature or new bone (Fig. 6). In addition, fractional analysis of the polarized light specimens demonstrated fractal patterns suggestive of woven bone modeling. Alveolar Bone Modeling with a Fixed, Continuous-Arch Appliance

In recent years, fixed, passive self-ligating (PSL) appliances have been developed along with low-friction/low-force, continuous-arch protocols for orthodontic treatment. Dr. Hisham Badawi has reported evidence with his OSIM apparatus supporting the ability of passive self-ligating brackets to deliver lower-magnitude forces compared with elastomeric-ligated appliances applied to the same malocclusion in an in vitro model (Fig. 7). Evidence has also been reported supporting the ability of passive self-ligating brackets to achieve a reduction in the frictional resistance to sliding at the bracket/wire interface. The resultant load applied to the teeth and transmitted to the alveolar bone excessively decreases as the fractional resistance to sliding and the force required to overcome it decreases. Clinical evidence has been reported demonstrating significant widening of the dental arches following treatment with the low-friction/low force Damon System. An increase in the transverse dimension of the alveolar bone has also been reported in response to the low biomechanical load delivered by this treatment regimen.

The following case reports provide examples of the alveolar bone modeling authors have observed over a combined 28 years of experience utilizing the Damon passive self-ligating fixed appliance and treatment protocols advocated by Dr. Dwight Damon.

CASE STUDY 1
CHILD ALVEOLAR MODELING: Pretreatment

diagnosis
A 9-year-old male patient presented in the mixed dentition with premature loss of his maxillary left primary canine with space loss and a blocked-out, unerupted permanent canine. His mandibular arch presented with severe crowding and completely blocked-out and unerupted permanent incisors. He exhibited normal circumdental muscle tonus and lip competence. The lateral cephalometric analysis of the polarized light specimens demonstrated significant widening of the dental arches following treatment with the low-friction/low force Damon System. An increase in the transverse dimension of the alveolar bone has also been reported in response to the low biomechanical load delivered by this treatment regimen.

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Child Alveolar Modeling: Pretreatment

Pretreatment

Posttreatment

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
CASE STUDY 2

PERIADOLESCENT ALVEOLAR MODELING:

Pretreatment

Diagnosis

An 11-year-old female patient presented with a Class I jaw relationship and severe tooth size/arch length discrepancies with 9 mm of crowding in the mandibular 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 tone 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 .015” Copper Ni-Ti wires and Ni-Ti open-coil springs activated one half of a bracket width to begin to create space for the unbracketed, blocked-out teeth. Eyepot 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 engage 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 retigated and the patient reappointed for 8 weeks.

Although in significantly crowded cases the transitional wire is typically a .015” Copper Ni-Ti wire engaged in preparation for a .016” x .022” Copper Ni-Ti wire, at the ninth week bracket alignment was again deemed insufficient for rectangular wire engagement so a .016” Copper Ni-Ti wire was placed. The springs were reactivated and the blocked-out teeth retigated. 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 .015” Copper Ni-Ti wires until 12 months into treatment.

Results

The final result was obtained after 27 months of treatment. Retention included bonded lingual wire retainers and clear, vacuum-formed Essex-style removable retainers to be worn while sleeping. Sizecorrected 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 frequent removable retainer wear and the alveolar modeling obtained had remained remarkably stable.

PERIADOLESCENT ALVEOLAR MODELING:

Pre-/Posttreatment Comparison Demonstrates Alveolar Modeling

**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 alveolar bone. The collapsed buccal segments and retruded 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 turbo 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 .012” and .015” (6.5 months) Copper Ni-Ti followed by .016” x .025” “Copper Ni-Ti (8 weeks each). The case was finished in .019” x .025” “TMA (upper) and .017” x .025” “TMA (lower).

Results

The case result was obtained in 19 months. The light, bioengineered load transmitted to the alveolar 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 to the patient’s mandibular arch.
PERIADOLESCENT ALVEOLAR MODELING: Results

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

Stable Results 6.5 Years Posttreatment

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.

ADULT ALVEOLAR MODELING: Pre-/Posttreatment Comparison Demonstrates Alveolar Modeling. Surgery was Precluded in this Case.

CASE STUDY 4
ADULT ALVEOLAR MODELING:
Pre-treatment

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 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
Discussion
The cases report presented demonstrate the ability of the archwire to be kept low, the resultant force acting along the continuous 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 modeling.

As Frankel had done previously with his Function Regulator appliance, Damon has proposed a mechanism of action for the Damon appliance. Specifically, the anterior component of the force acting along the continuous archwire is kept low. It is mitigated by the resting pressure of the lips in patients with adequate circumoral muscle tonus. The posterior component of force is likewise resisted by multi-rooted molars along with the ascending rami of 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 XSIM findings of Badawi support Damon’s proposed mechanism of action, specifically the assertive of a lower anterior vector of force delivered with a passive self-ligating appliance compared with an elastic- 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 perosteal surfaces resulting from net apposition. 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 XSIM 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 elastic-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 Melvin and Allais.

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 sec-

Conclusions
This article presents case reports demonstrating a change in the size and shape of the alveolar bone in children, adolescent and adult patients treated by a continuous-arch, self-ligating appliance. These cases, along with the 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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