Clinical Applications of Mini-implants as Orthodontic Anchorage and the Peri-implant Tissue Reaction Upon Loading

Heon Jae Cho, DDS, MS, PhD

ABSTRACT

Orthodontic tooth treatment depends on anchorage for improved results. There are many different sources of orthodontic anchorage. Segments of teeth or the entire arch have been the most common type of orthodontic anchorage. But in challenging situations, orthodontists frequently need extra-dental supplements of anchorage such as headgear, face mask, and intermaxillary elastics. Most of them require the patient's compliance. Recently, temporary mini-implants placed within the bone tissue have been used as orthodontic anchorage. It has been proven in many studies and case reports that the mini-implant is a very reliable anchorage source clinically and histologically.

The purpose of this article is to introduce the basic clinical application of mini-implants as orthodontic anchorage and to discuss basic concepts about the tissue reaction of peri-implant bone upon placement and loading either from orthodontic mechanics and/or function in the orthodontic treatment of the patients.

It is possible for mini-implants to supply absolute anchorage even though they may move slightly within the bone tissue without losing clinical stability. The primary application of mini-implants as orthodontic anchorage will be cases that need absolute anchorage for desired tooth movement.

Case 1

The first case is of a female patient, age 19 years, 11 months. The patient's chief complaint was lip protrusion. In the initial lateral cephalograph, her upper and lower incisors were severely proclined (**Figures 1a-i**).

Her problem list included having severe lip protrusion, severe upper and lower incisor protrusion, (**Figure 1j**). The patient wanted an invisible appliance.

Treatment objectives were to reduce upper and lower lip protrusion as much as 100 percent retraction of incisors into bicuspid extraction space possible, achieve class I molar and canine relationship, and normal OJ/OB.

The treatment plan included four first bicuspids extraction, retraction of upper and lower incisors with maximum anchorage, if possible, and using a custom-made lingual retractor for incisor retraction because the patient wanted to use an invisible appliance.

Specially designed, custom-made lingual retraction appliances were used. The primary mechanical property for the lingual retractor is rigidity because the goal was to retract six incisors as a segment without individual tooth movement (**Figures 1k-**

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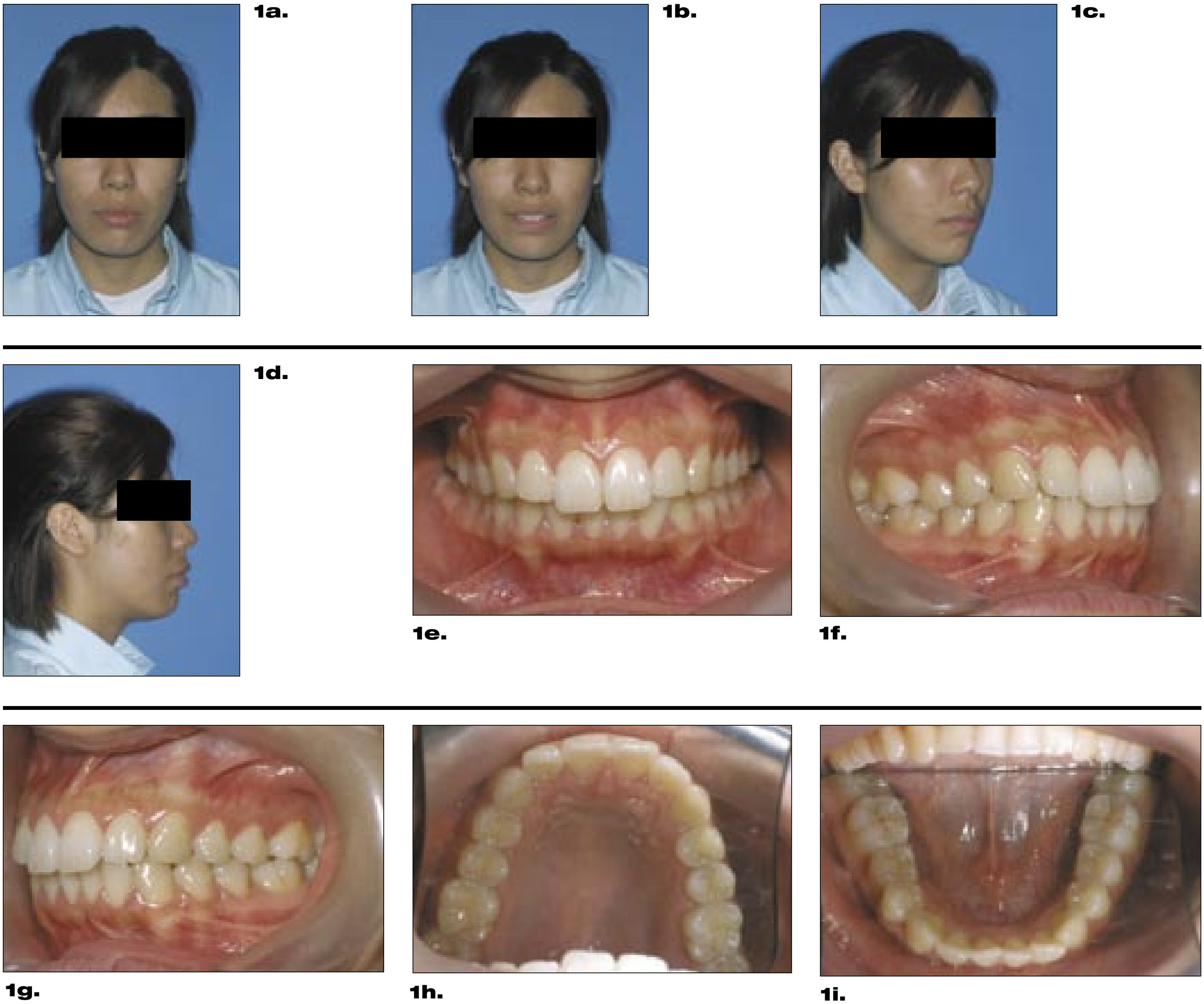
CASE 1



Figures 1a-i. Initial facial and intraoral photos.

CASE 1

1j.

1k.

1l.

1m.

1n.

1o.

1p.

1q.

1r.

Figure 1j. Initial cephalometric radiograph.

Figures 1k-l. Lingual retractors.

Figure 1m. Lateral cephalometric radiograph with lingual retractors.

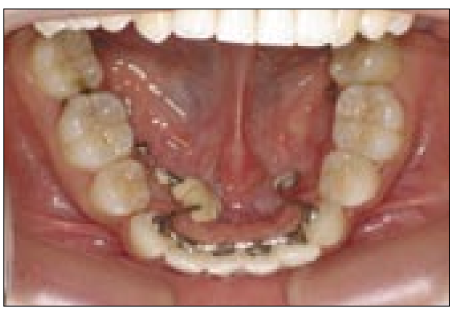
Figures 1n-r. Progress facial and intraoral photos.

CASE 1

1s.

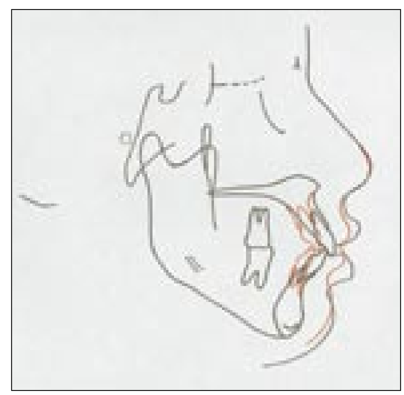
1t.

1u.



1v.

1w.



1x.

Figures 1s-v. Progress facial and intraoral photos.

Figure 1w. Progress cephalometric radiograph.

Figure 1x. Superimposition between initial and progress lateral cephalometric radiographs.

m). A 0.045 inch stainless-steel wire was used for fabrication of the lingual retractors. Two mini-implants were placed in the palatal area and another two mini-implants were placed in the lingual interradicular space between the lower first and second molars (**Figures 1k-m**). Nickel titanium coil springs were used to retract six incisors as one segment. Retraction forces were delivered to the hooks of the extended arms of lingual retractors from mini-implant anchorage. The resulting vectors were designed to pass through the centers of both incisor segments (**Figure 1m**). The result shows that her lip protrusion was reduced significantly (**Figures 1n-q**) and that the posterior occlusion was maintained (**Figures 1r-t**). There were no forces applied to the molars during treatment. The post-treatment lateral cephalometric radiograph showed that the upper and lower incisors had improved in their inclinations within basal bone (**Figure 1w**).

Superimposition of the lateral cephalometric X-ray showed that upper and lower incisors were retracted very efficiently without any forward movement of posterior teeth (**Figure 1x**) and thus the mini-implants served as absolute anchorage for this patient to retract incisors. The movement of incisor retraction is similar to that of surgical retraction of the anterior segment with subapical osteotomy (**Figure 1x**). At this point, the lingual retractors were removed for the finishing lingual appliance, however, the patient refused to have any further treatment because she felt that the esthetic results were exactly what she wanted and she did not have any functional problems. Despite a request for less than six months finishing treatment with lingual appliance, she did not want any further treatment.

Case 2

This case is a female patient, age 20 years, 3 months old. Her chief complaints and major problem list were anterior open bite and spacing (**Figures 2a-i**).

The primary treatment objective was the correction of an anterior open bite by intruding the posterior maxillary teeth either by surgery or orthodontic intrusion. The patient had a good vertical position of upper incisor relative to upper lip (3 mm incisor stomion). She also had a long lower facial height, which would indicate that incisor extrusion for open bite correction would not result in good post-treatment esthetics and stability. Other objectives were to close all the anterior spaces, achieve class I molar and canine relationship, and achieve a normal overjet and overbite.

The treatment plan was to intrude posterior teeth orthodontically in order to correct the anterior open bite since the patient refused a surgical option.

Two midpalatal mini-implants with a rigid transpalatal arch (.036") were used to intrude the maxillary posterior teeth (**Figures 2k-m**). The anterior open bite was corrected by a maxillary molar intrusion (**Figures 2n-r**).

The comparison between initial and progress cephalograms clearly showed the maxillary posterior teeth and TPA were intruded (**Figures 2m-s**). The treatment effect from the intrusion of posterior teeth was very similar to that from surgical maxillary posterior impaction since both induce the mandibular closing rotation.

Discussion

Two typical applications of mini-implants as orthodontic anchorage were shown. However, there are many other indications for mini-implants as orthodontic anchorage, such as molar protraction, molar distalization, presurgical orthodontic preparation, prerestorative tooth movements (uprighting, intrusion of severely extruded unopposed tooth/teeth, space redistribution, and reduction of size of the edentulous span, etc.). There are numerous case reports using mini-implants as orthodontic anchorage.[1-7]

Traditionally, the orthodontic molar intrusion was very difficult tooth movement because it was not easy to get adequate anchorage for molar intrusion. Mini-implants served very nicely as an adequate anchorage source for molar intrusion and anterior retraction for these patients.

Peri-implant Tissue Reaction Upon Loading

Premature loosening of mini-implants is one of most common problems in the usage of mini-implants as orthodontic anchorage. In order to have good stability, it is very important to understand the peri-implant tissue reaction upon implantation and loading whether it is therapeutic (orthodontic), functional, or combined. Initial stability of mini-implants depends on solid mechanical locking of thread of mini-implants into cortical bone.[8] After successful healing, the entire osseous tissue connecting the implant to host bone was entirely lamellar bone.[9] Trisi reported that, after two-month healing and four-month loading, an almost continuous trabeculum layer of bone, 100 to 200 m thick, surrounded the implant surface.[8] Bone, like other relatively rigid materials, is subject to fatigue.

There are numerous studies about bone responses around mini-implants.[8-20] Upon loading, whether it is from therapeutic (orthodontic) or function, there will be microstrain in the peri-implant tissue because there is a large mismatch between the modulus of elasticity of bone and that of a titanium mini-implant. The peak strain history (bone deformation over time) of dynamic (normal cyclic) loading is related to the magnitude and frequency of functional loads. Bone cells are sensitive to strain (deformation) along functionally loaded bone surfaces. Frost proposed a biomechanical relationship for skeletal adaptation, referred to as the "mechanostat."[21-24]

Biomechanical control of osseous adaptation (bone modeling and remodeling) is related to the magnitude and frequency of dynamic (intermittent) loads. Bone is a composite biomaterial that structurally adapts to its mechanical environment. Suboptimal loading results in atrophy of both bone mass and structural orientation. The peak strain history (bone deformation over time) dictates the osseous response. Bone deformation (strain) is expressed as microstrain (μE), which is strain x 10^{-6}. The upper limit of the physiological loading range for steady-state maintenance of bone is only about 10 percent of its ultimate strength (2500/25000μE). Repetitive loading at more than 4000μE results is pathological overload and will induce eventual fatigue failure of bone.[21-24] The formation of microdamage or microscopic cracks in the bone matrix has been associated with elevated or altered strain environments and with fatigue loading.[25-29] Bone microdamage is manifested by the presence of well-defined microcracks in lamellar bone tissue.[10] Microcracks refer to discrete and microscopically visible flaws that may progress and eventually lead to a complete failure of the trabeculum. Trisi reported microcracks either around implants placed in cortical bone or in peri-implant cancellous bone.[10]

Previous studies reported that the remodeling of the peri-implant bone remains elevated throughout the implant's life when implants are under load.[30,31] This increased turnover (remodeling) rate is a natural repair process of microdamage in bone and fibrous tissue.[32] Thus, late (secondary) stability of mini-implants within the bone tissue depends upon the balance between accumulated microstrain of peri-implant bone tissue and density of peri-implant bone and its healing capacity (rate of remodeling).

CASE 2

2a.

2b.

2c.

2d.

2e.

2f.

2g.

2h.

2i.

Figures 2a-i. Initial facial and intraoral photos.

Figure 2j. Initial cephalometric radiograph.

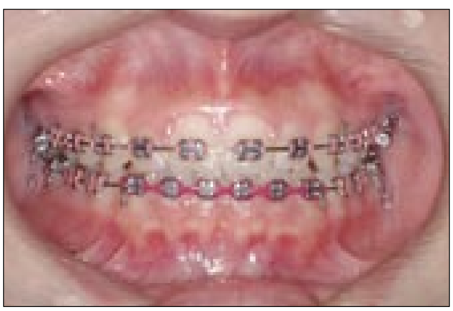
2j.

CASE 2

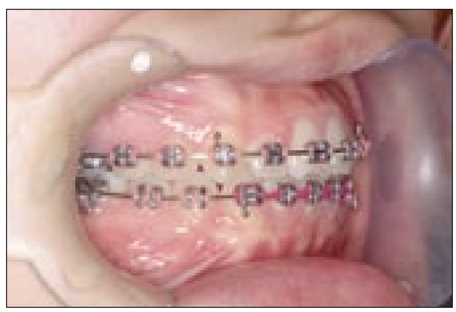
2k.

2l.

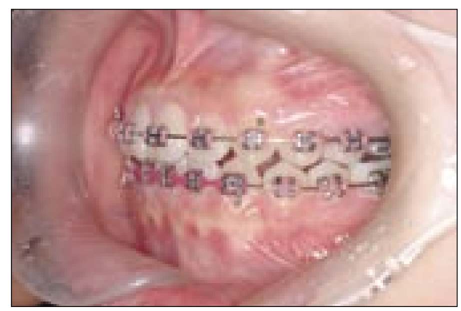
2m.



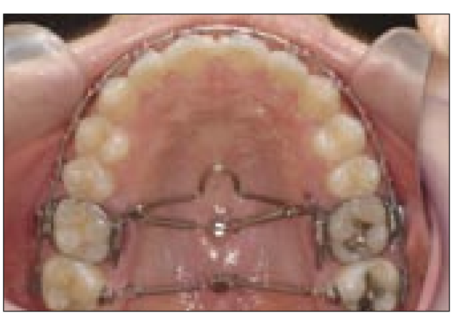
2n.



2o.



2p.



2q.

2r.

2s.

Figures 2k-l. Appliance for maxillary molar intrusion.

Figure 2m. Lateral cephalometric radiograph with maxillary molar intrusion appliance.

Figures 2n-r. Progress intraoral photos.

Figure 2s. Progress cephalometric radiograph.

Besides premature loosening, there are some other possible complications from usage of mini-implants as orthodontic anchorage. These include possibility of root damage, risk of infection, and soft tissue irritation at/near the site of mini-implant placement. Sometimes, subjective discomfort from soft tissue irritation makes it impossible to use the mini-implants as sources of orthodontic anchorage.

Conclusion

The cases shown in this article demonstrate the effective use of a mini-implant as an orthodontic anchorage to solve difficult problems during orthodontic treatment that have very limited solutions available.

There are some potential complications from these new devices, but well-placed and well-maintained mini-implants can be great anchorage solutions for various challenging orthodontic cases.

In order to use this new tool more properly, it may be necessary to understand the reaction of tissues surrounding the mini-implants upon placement and loading. ■■■■

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