Biomechanics of Skeletal Anchorage
Part 1 Class II Extraction Treatment

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The outcome of orthodontic treatment often depends on the preservation of posterior anchorage. In recent years, "absolute" skeletal anchorage has been introduced,[1] with conventional dental implants,[2] palatal implants,[3] miniscrews,[4,5] and miniplates[6,7] used successfully in clinical cases. Most of the reports on skeletal anchorage, however, have focused on the implant design, the surgical insertion technique, and the stability of the implants after orthodontic loading.[8] Descriptions of the biomechanical principles of various clinical applications have been limited.[9]

Skeletal anchorage is most commonly used in adult Class II treatment after the extraction of two upper premolars. For indirect anchorage, a midpalatal implant is usually connected to two premolars or molars with a transpalatal arch.[10,11] For direct anchorage, a miniscrew or miniplate is inserted near the upper first molar during retraction of the anterior segment, and nickel titanium coil springs or elastics are used to connect this bone anchor with the anterior segment.[12] In most cases, the incisors and canines are distalized simultaneously by sliding mechanics.

Skeletal anchorage has also been recommended for closure of a skeletal open bite by intrusion of the buccal segments and subsequent autorotation of the mandible,[13] for preprosthetic molar uprighting or intrusion,[14] and for space closure in cases with agenesis of the lower second premolars.[15]

This two-part series describes the biomechanics of skeletal anchorage in Class II treatment with and without premolar extractions.

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Appliance Design and Technique

Our bone anchor has three parts: a two- or three-hole titanium miniplate, .7mm thick; a neck made from a round bar, 1.4mm in diameter; and a cylindrical fixation unit with a locking screw (Fig. 1A). Monocortical titanium screws, 5mm or 7mm in length and 2.3mm in diameter, are inserted through the holes in the miniplate (Fig. 1B). All bone anchors are inserted under local anesthesia. A pilot hole, 1.6mm in diameter, is drilled before the insertion of each screw.

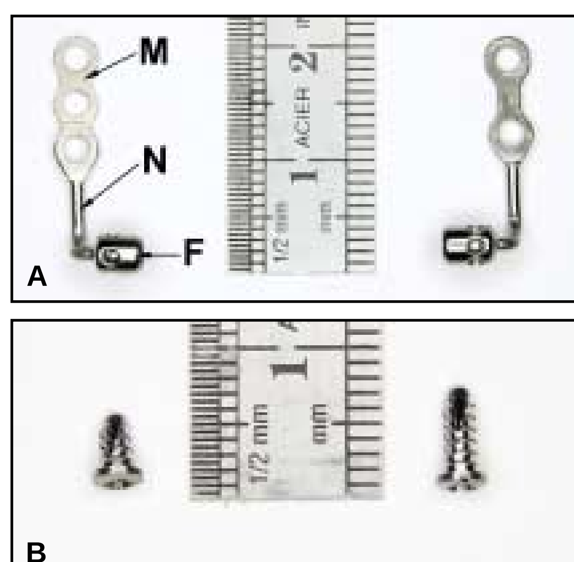


Fig. 1 A. Three-hole miniplate (M) with neck (N) connected to cylindrical fixation unit (F). B. Titanium miniscrews, 5mm and 7mm long.

The fixation unit contains two 1.1mm-diameter slots. Using the locking screw, a square wire as large as .032" × .032" can be engaged in one of the slots to connect the bone anchor to the fixed orthodontic appliance. By changing the shape and length of the connecting wire, the point of orthodontic force application can be adjusted to provide the required direction of traction.

Over a period of four and a half years, we have placed 276 of these bone anchors in 137 patients. The most common location has been the zygomatic buttress (212 patients), followed by the lower canine region (44), the posterior portion of the mandible (14), and the nasal process of the maxilla (six). In 31 patients, 59 bone anchors were placed in the upper infrazygomatic crests to correct Class II malocclusions after extraction of the upper first premolars.

All cases have been bonded with .018" × .025" standard edgewise brackets. For the upper

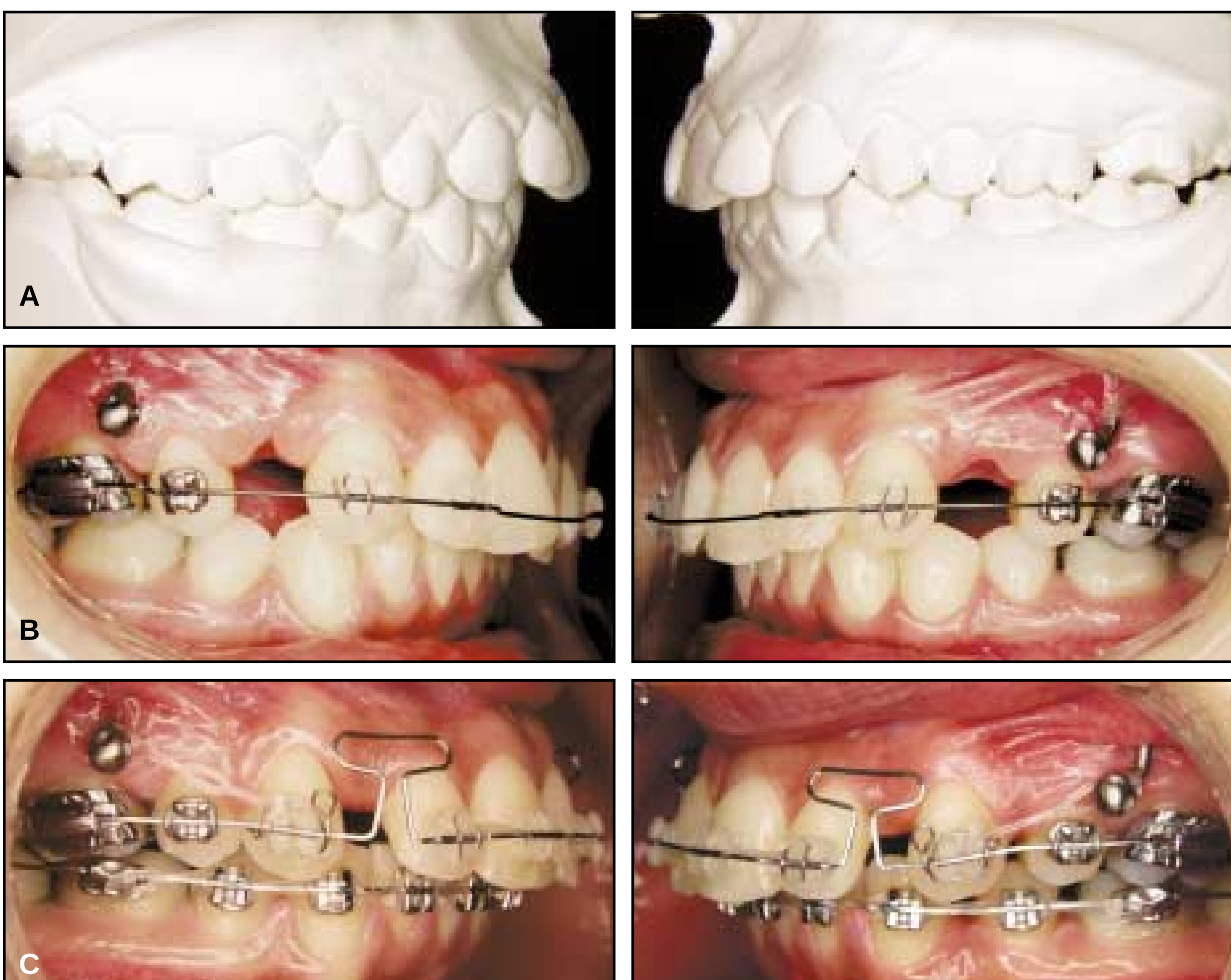
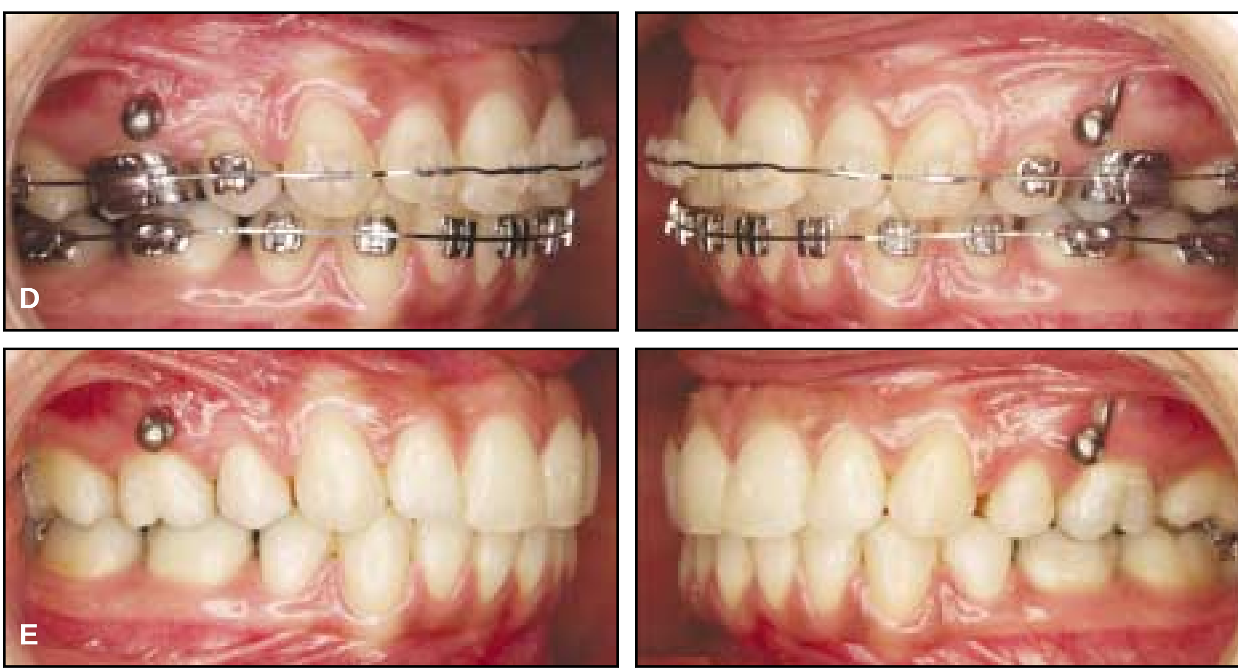


Fig. 2 A. 22-year-old female with full Class II canine relationship, excessive overjet, and missing lower right first premolar before treatment. B. After extraction of upper first premolars, upper canines are distalized with elastics to bone anchors, without bonding upper incisors. C. Remaining overjet corrected with T-loop arch while Class I relationship is maintained with elastics between canines and bone anchors (continued on next page).

anterior teeth of adult patients, we use preadjusted ceramic brackets (Roth prescription) with .014" Kobayashi hooks. After extraction of the first premolars, the maxillary buccal segments are leveled with .014" nickel titanium archwires. To avoid increasing the overjet by protruding the upper incisors, we do not bond all the incisors to correct anterior crowding during the initial stage. The canines are distalized first, using sliding mechanics along an .016" Australian* or .016" × .016" stainless steel archwire (Fig. 2B). The distal wings of the canine brackets are tightly tied to the archwire with .010" ligature wires to avoid unwanted rotations. Elastic forces of 100-130g are used between the canines and the extensions of the fixation units, with the patient asked to change the elastics daily. Once the canines have reached a Class I relationship, incisor retraction and bite opening are accomplished using an .016" × .022" stainless steel archwire with T-loops distal to both lateral incisors (Fig. 2C). After correction of the sagittal and vertical overbite, continuous arches are used for finishing (Fig. 2D).

*G&H Wire Company, P.O. Box 248, Greenwood, IN 46142.



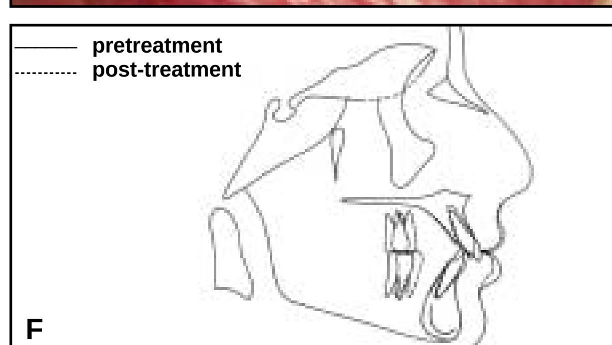


Fig. 2 (cont.) D. Finishing with continuous arches. E. Final occlusion after 21 months of treatment. F. Superimposition of cephalometric tracings before and after treatment.

Biomechanics

Friction is usually considered undesirable in sliding mechanics. Wire section—round, square, or rectangular—and dimension[16] play an important role, as do the alloy properties[17] and bracket design. Self-ligation appears to minimize friction,[18] while ceramic bracket slots have proven less effective.[19] Regardless of the appliance, however, when skeletal anchorage is used, the friction between brackets and archwire can actually help correct the overjet in the early stages of treatment, thus reducing overall treatment time (Fig. 3).

In conventional sliding mechanics, the upper canine is distalized with an elastic between the canine bracket hook and the first molar. The force is applied to the canine bracket at some distance from its center of resistance, producing a moment that tips the crown distally at first (Fig. 4). This tipping pushes the upper mesial and lower distal portions of the slot against the archwire, increasing friction at the bracket-archwire interface and pulling the archwire distally. Similarly, when the elastic is attached to the hook on the first molar tube, located below its center of resistance, the resultant mesial crown tipping causes friction in the molar tube,

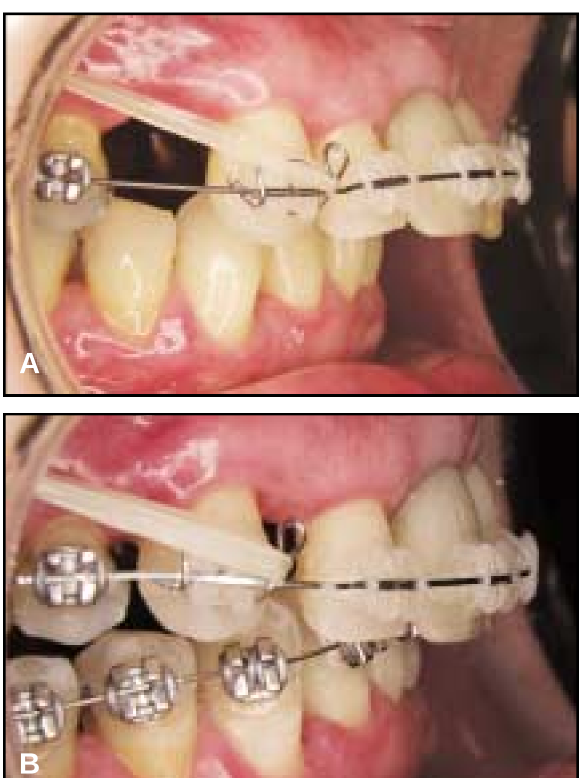


Fig. 3 A. Elastic between canine and bone anchor used to distalize canine with sliding mechanics. B. Overjet reduced during distal canine movement until contact is made with lower incisors.

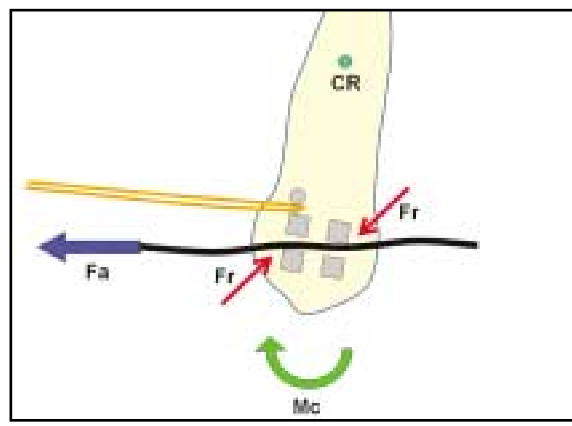


Fig. 4 Moment at canine (Mc) and initial crown tipping increase friction (Fr) between archwire and bracket, pulling archwire distally (Fa).

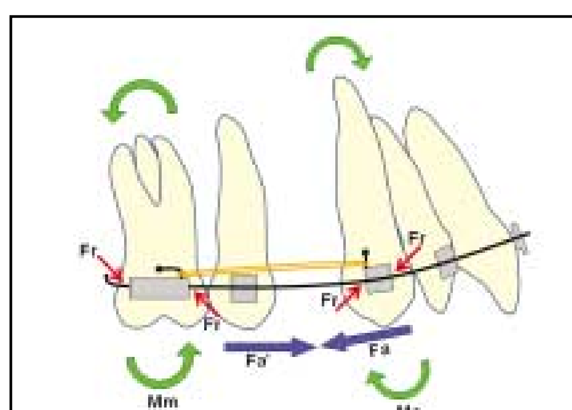


Fig. 5 Friction (Fr) in canine bracket pulls archwire distally (Fa) while friction in molar tube pulls archwire mesially (Fa'). Moments at canine (Mc) and molar (Mm) tend to neutralize each other.

pulling the archwire forward. These frictional forces tend to neutralize each other (Fig. 5), which may explain why the overjet is not reduced when the first molars are used for posterior anchorage during canine retraction.

On the other hand, when the elastics are attached from the canine bracket to a miniscrew or miniplate in the first molar region, the distal traction on the archwire created by friction in the canine bracket is not counterbalanced by mesial traction from friction in the molar tube (Fig. 6). If there is no contact between the upper and lower incisors, the resulting force will pull the archwire and the four upper incisors distally, reducing the overjet. Therefore, the six anterior teeth should not be tied together and distalized simultaneously with sliding mechanics, which would require bite opening early in treatment. The incisors will spontaneously follow the movement of the canines until they make contact with the lower incisors, as long as there is no interposition of the lower lip and the intercuspation is not too tight in the buccal segments. Space will be created between the lateral incisors and the canines, especially in deep-bite cases.

The remainder of the overjet and overbite can easily be corrected with a T-loop arch once the canines have reached a Class I relationship (Fig. 7). The intrusive forces required for bite opening in the anterior segment generate reactive forces, distal to the T-loops, which tend to cause canine extrusion. In a Class I occlusion, however, the vertical support of the lower canines and first premolars counteracts the canine extrusion and helps open the bite. To retract the incisors, the T-loops are opened slightly by bending the archwire distal to the first molar tubes. This creates a reactive force that pushes the molars forward. To avoid rotation of the first molars around their palatal roots, a transpalatal arch should be placed. The Class I relationship in the buccal segment is maintained by elastic traction between the canines and the bone anchor, which adds a small intrusive component of force to the canines.

In cases with asymmetric occlusion, the skeletal anchor is placed on the side opposite the upper midline shift. When only one of the canines is moved distally by an elastic connected to the bone anchor, the friction in that canine bracket will pull the archwire to one side, partially correcting the overjet and midline shift (Fig. 8B). The lateral incisor will begin to follow the canine as the supracrestal periodontal fibers are stretched (Fig. 9B). As the canine relationship approaches Class I, a second elastic is attached between the central incisor and the bone anchor (Fig. 8C). To avoid gingival irritation, this elastic is "zig-zagged" around

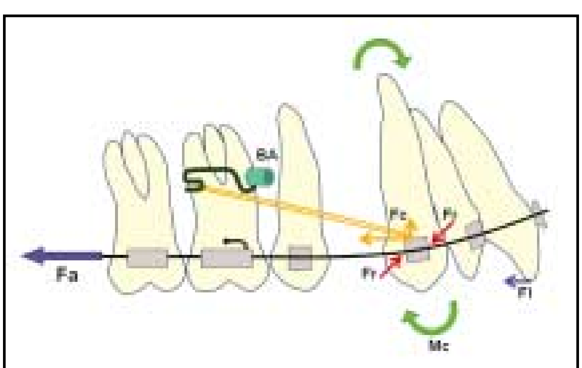


Fig. 6 Elastic attached to bone anchor (BA) exerts force on canine (Fc). Friction (Fr) in canine bracket pulls archwire distally (Fa), which also pulls incisors distally (Fi).

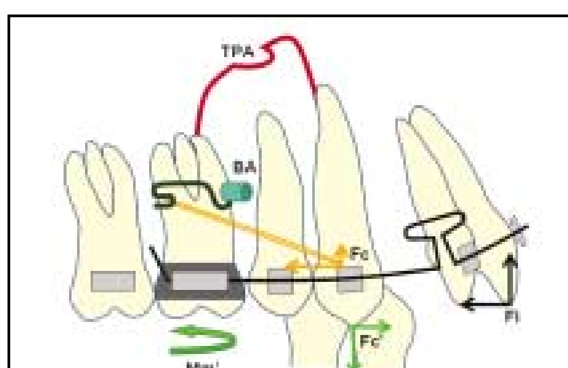
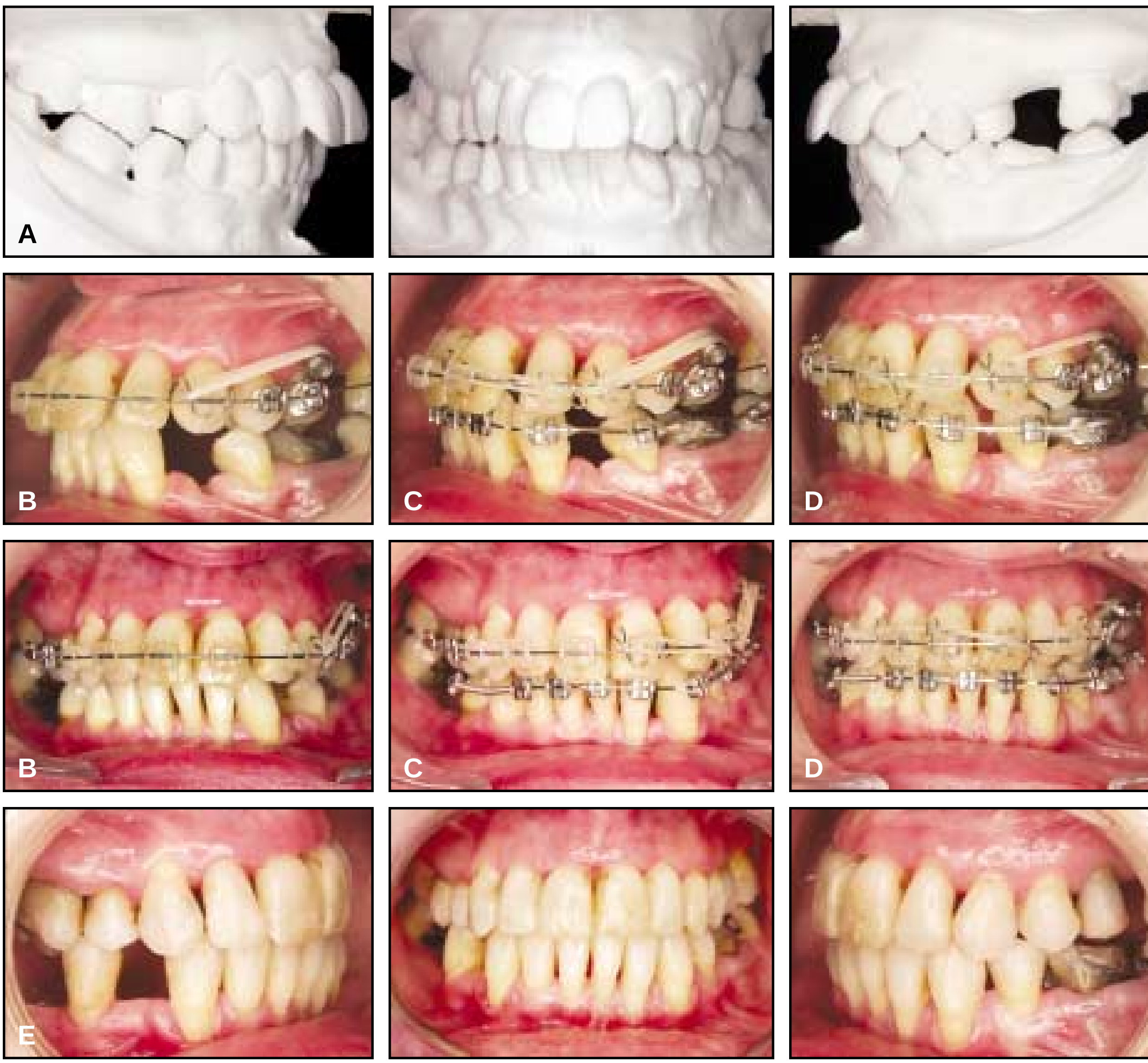


Fig. 7 T-loop arch intrudes and retracts incisors (Fi). Reactive forces generate extrusion and mesial movement of canine (Fc'), while transpalatal arch (TPA) counteracts molar rotation (Mm').



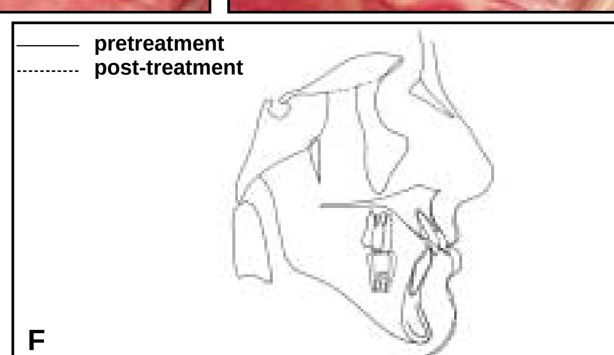


Fig. 8 A. 42-year-old female Class II patient with excessive overjet and upper and lower midline deviation to right. Lower right second molar was extracted due to endodontic problem. B. After extraction of lower left first premolars, upper left canine and premolars are distalized simultaneously by sliding mechanics, with lateral incisor following canine movement. C. Elastics from upper left canine and central incisor to bone anchor. D. "Zig-zag" elastic from upper right lateral incisor to bone anchor. E. Final occlusion after 25 months of treatment. F. Superimposition of cephalometric tracings before and after treatment.

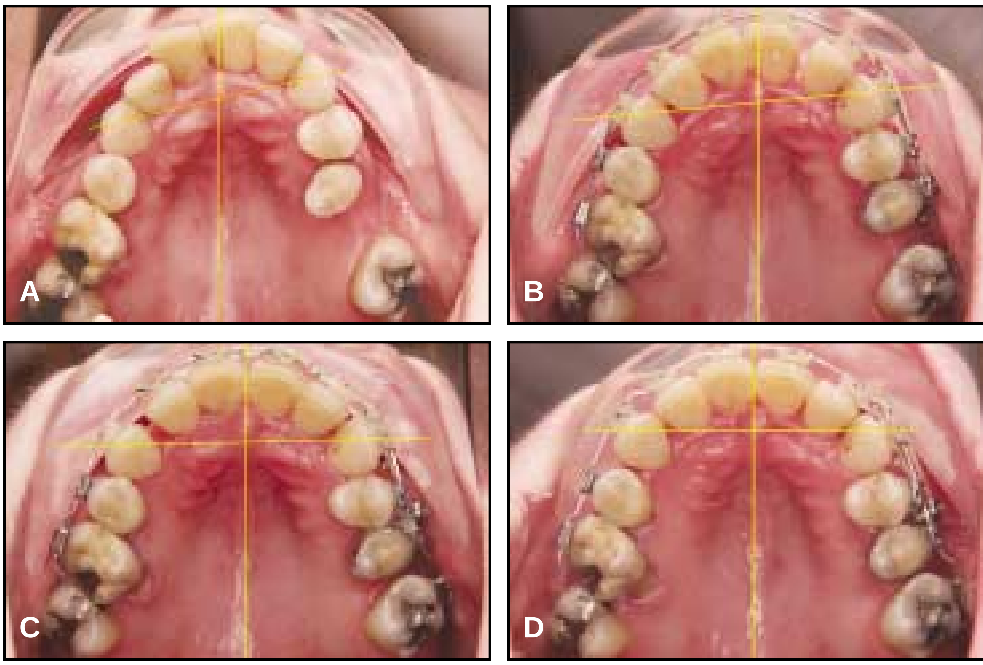


Fig. 9 A. Asymmetrical upper canines at start of treatment. B. Lateral incisor following spontaneously during distal movement of upper left canine and premolar. C. "Zig-zag" elastic from upper right lateral incisor to bone anchor. D. "Zig-zag" elastic also moves upper right canine mesially to restore canine symmetry.

another Kobayashi hook on the lateral incisor. Both elastics should be changed daily by the patient. Once the central incisor contacts the lateral incisor, the central and lateral incisors on the opposite side are moved in the same way, using a "zig-zag" elastic attached to the skeletal anchor (Fig. 8D). Thus, the entire dental arch and midline can be moved toward the bone anchor (Fig. 9).

Another major difference between skeletal anchorage and conventional biomechanics can be observed in the transverse dimension. When an elastic is attached between the upper canine and first molar, the canine and molar tend to rotate in opposite directions as viewed from the occlusal (Fig. 10A). These rotations neutralize each other, with little effect on arch width. When the elastic from the canine bracket is connected to a miniplate or miniscrew in the molar region, however, there is no rotation of the first molar. The initial canine rotation then tends to push the distal end of the archwire toward the midline (Fig. 10B). This explains why crossbites can appear during distal movement of the canines with skeletal anchorage. To avoid reduction of the intermolar width, the second molars should be bonded or a transpalatal arch should be placed (Fig. 10C).

When a bone anchor is placed in the apical area of the molar region or on the infrazygomatic crest, the line of force connecting the canine with the bone anchor is directed slightly upward. This may be useful in eliminating occlusal interferences during distal movement of the canine, and it also adds an intrusive component of force to the anterior segment, which may help level a deep bite. In cases with anterior open bite, however, more horizontal traction is preferable. Either the miniscrews should be placed lower, which would increase the risk of root damage during insertion, or extensions should be used to bring the point of force application downward (Fig. 11). The shorter the distance between the bone anchor and the canine, the smaller the sagittal component of force

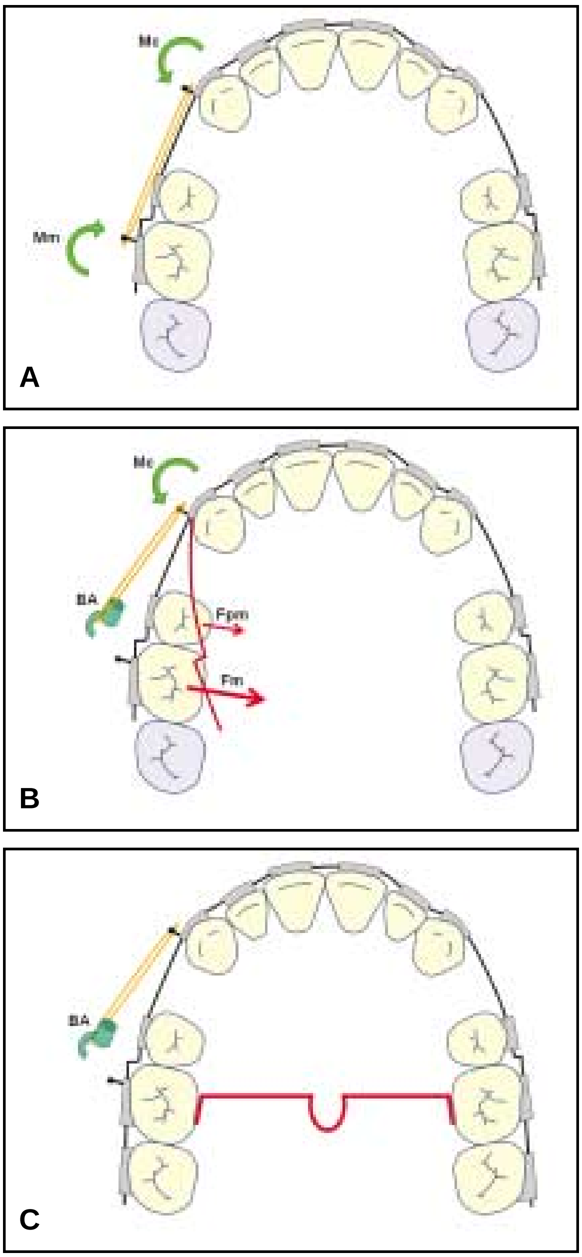


Fig. 10 A. Elastic between molar and canine creates rotational moments (Mm and Mc) that tend to neutralize each other. B. With elastic between canine and bone anchor (BA), moment on canine (Mc) pushes distal end of archwire toward midline, also pushing first molar (Fm) and premolar (Fpm) toward midline. C. To counteract moment, either second molars should be bonded or transpalatal arch should be inserted.

Fig. 11 Horizontal traction in case with open-bite tendency. S-extension of bone anchor brings posterior point of force application downward.

will be. This distance can be reduced either by inserting the miniscrew between the first and second molars or by using an extension to move the point of force application distal to the first molar. From an occlusal point of view, the line of force is oriented toward the outside, away from the midline (Fig. 10B), and is thus responsible for some expansion in the anterior segment.

Discussion

Over the past four and a half years, we have successfully used 59 bone anchors in the infrazygomatic crests to retract the upper anterior teeth after extraction of first premolars. The stability of the skeletal anchors increases with time, but if they are left in place until the completion of orthodontic treatment, their removal may be complicated by bone apposition over the miniplates. We therefore recommend that the miniplates be removed as soon as the anchorage is no longer needed.

Local infection has reportedly been caused when the flat section of a conventional miniplate perforates the soft tissue,[7] making oral hygiene more difficult. Such an infection could cause bone loss around the miniplate, resulting in increased mobility of the bone anchor. Only one of 59 bone anchors has been lost due to hypermobility, however, probably because the round connecting bar improves adaptation to the soft tissues, facilitates oral hygiene, and minimizes submucosal bacterial infiltration. The key to successful skeletal anchorage is good "soft-tissue management".[20]

Depending on the severity of the Class II relationship, we usually obtain a Class I canine occlusion after only six to nine months of treatment. At that point, some of the overjet has already been eliminated. Because of the friction in the canine brackets, the upper incisors spontaneously follow the canines until they contact the lower incisors. Bite opening is more efficient later in treatment due to the stable occlusion in the buccal segments. Correction of incisor crowding can be postponed until space has been created by the distal canine movement, thus minimizing unwanted incisor protrusion. This is in contrast with straightwire mechanics,[21] where leveling of the incisors and correction of the deep bite are started early in treatment.

Conclusion

The biomechanics involved in skeletal anchorage are slightly different from those in conventional sliding mechanics because of the absence of some reactive forces. The reliability of this "absolute" anchorage improves treatment efficiency and reduces treatment time, which largely compensates for the discomfort and cost associated with the placement and removal of the bone anchors. Furthermore, in Class II cases treated with premolar extractions, skeletal anchorage reduces the need for extraoral devices and other auxiliaries such as Nance appliances and Class II elastics, thus improving both patient comfort and patient compliance.

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