Clinical Applications of Predictable Force Systems

Part 2  Miniscrew Anchorage

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(Authors’ Note: Dr. Charles Burstone, one of the great minds in orthodontic history, dedicated his life to advancing our specialty through academics and research. His life’s work, and most notably his contributions to the study of biomechanics, have had a considerable impact on the way we practice orthodontics today. With these articles, we pay tribute to his memory and to all that he did for us as a teacher, icon, innovator, visionary, and clinician.)

Part 1 of this Overview described one- and two-couple force systems and conventional orthodontic methods of utilizing them. The one-couple system has the advantage of improving the predictability of the applied force and hence the ability to anticipate side effects on the anchorage units. Even with the most controlled system, however, it is common to see unwanted side effects on the anchoring dentition. If an attempt is made to control these side effects through the use of intermax-
Fig. 18  A. 14-year-old male patient with impacted maxillary canines before treatment.  B. Direct anchorage of cantilever from infrazygomatic miniscrew to impacted right canine.  C. Force diagram of clinical set-up.  D. Initial placement of cantilevers to extrude maxillary canines.  E. Patient after six months of extrusion.  F. Patient after 10 months of extrusion.
illary elastics and compliance is not ideal, the outcome may be less than optimal.

In Part 2, we will present a number of cases illustrating the application of one-couple systems in conjunction with skeletal anchorage. This approach eliminates undesirable side effects on the dentition by transferring the orthodontic forces to a bone-borne anchor. Miniscrews in particular have become increasingly popular due to their relative ease of placement and removal and their numerous clinical applications. They have demonstrated good patient acceptance and relatively low failure rates—most recently reported at around 13.5%. The main factors associated with miniscrew failure include the length and diameter of the screw, the quality and thickness of cortical bone, and the initial loading force. In addition, excessive torsional force on the miniscrew may contribute to failure.

Theoretically, if the force applied by a cantilever to a tooth or the arch is placed perpendicular to the long axis of the miniscrew, a torquing moment will be exerted on the screw head in either a clockwise or counterclockwise direction, as we will describe in more detail.

One-Couple Systems with Miniscrews: Direct vs. Indirect Anchorage

As outlined in Part 1, a cantilever is a one-couple system characterized, in a two-tooth model, by a vertical force on one tooth or segment and a moment created by an intrabracket couple on the anchorage segment, along with a vertical force in the opposite direction. This same biomechanical concept holds true when the anchorage is provided by a miniscrew.

With direct anchorage, the dentition is not included in the anchorage unit, so that any effects of the one-couple system are exerted directly on the miniscrew. Figure 18A shows a panoramic radiograph of a 14-year-old male presenting with bilaterally impacted maxillary canines. The upper right canine exhibited a mesial eruption pattern, and further assessment indicated a labial ectopic eruption pattern of both canines. Following periodontal exposure of the canines, placement of bonded attachments, and primary healing, a 2mm x 9mm self-drilling LOMAS* miniscrew was placed in an infrrazygomatic position on each side of the maxilla. The miniscrew head incorporates an .022" x .028" slot for ligation of a cantilever, thereby permitting the use of direct anchorage for eruption of the canines (Fig. 18B). Figure 18C illustrates the predicted forces on the miniscrew and the impacted tooth. In this patient, .017" x .025" CNA** cantilevers were ligated to the miniscrew heads and extended to the gold-chain attachments on the canines (Fig. 18D). Note that the left cantilever was attached distal to the bonded attachment on the canine, providing a distal force and moment to tip the canine crown distally in addition to the eruptive force. Figure 18E shows the patient six months later, when the upper left canine had nearly erupted and the right canine bulge was evident. At this stage, the right cantilever was shortened to allow distal tipping of the canine crown. Figure 18F shows the patient 10 months after initial traction, with the right canine bonded and engaged in an .016" nickel titanium overlay.

Another application of these principles is through the use of indirect anchorage. Here, the dentition serves as the anchorage unit, but the side effects are minimized by stabilization with a miniscrew. Figure 19A illustrates a 48-year-old female who presented with an ectopically erupted upper right canine and retained deciduous canine. Note the well-seated buccal occlusion. The treatment plan was to extract the deciduous canine and then to retract and erupt the permanent canine into an ideal position. Significant time would be required to upright and distalize the permanent canine, however, due to its inclination. For esthetic purposes and to maintain the ideal buccal occlusion, it was decided to minimize fixed appliances in the maxillary arch until the canine was nearly aligned. A 2mm x 9mm LOMAS miniscrew was placed in an infrrazygomatic position, the deciduous canine was extracted, and an eyelet was bonded to the distal surface of the permanent canine to allow for the placement of a .017" x .025" CNA cantilever. Figure 19B shows the predicted forces on the miniscrew and the impacted tooth. Figure 19C illustrates the patient six months later, when the upper right canine was bonded and engaged in an .016" nickel titanium overlay.

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Fig. 19  A. 48-year-old female patient with ectopic upper right canine and retained deciduous canine before treatment.  B. Initial phase of distal traction with direct anchorage from infrazygomatic screw to canine.  C. After six months, cantilever placed to complete canine movement, using indirect anchorage from mini-screw fixed to molar tube with rigid stainless steel wire.  D. Force diagram of clinical setup.  E. Patient after additional four months of treatment, with canine extruded and intrusion arch in place.
An .017" × .025" CNA intrusion arch was placed, and the indirect anchorage from the mini-screw was continued to control 2nd-order effects on the molar (Fig. 19E).

As we described in Part 1, an uprighting spring can apply a force and a moment to a single tooth or segment of teeth, resulting in uprighting or leveling. When this configuration is directly anchored to a miniscrew, a single vertical force is applied to the screw, with an opposite vertical force and moment on the tooth or segment to be uprighted. Figure 20 illustrates a 23-year-old male patient with severely mesially tipped lower right first and second molars after orthognathic surgery.

Because of the inclination of the molars, a substantial tipback moment would be required to upright and level this segment predictably. Leveling with straightwire mechanics and nickel titanium archwires had been unsuccessful over a number of months, most likely due to an insufficient moment.

direct retraction from the miniscrew with an elastomeric thread (Fig. 19B). An auxiliary tube was placed on the first molar to allow subsequent attachment of a cantilever. After six months of treatment, the canine had been retracted away from the lateral incisor, and a cantilever was then extended from the molar tube to a contact point on the gingival surface of the canine bracket. This produced a vertical extrusive force on the canine, with an intrusive force and counterclockwise moment on the molar due to the intrabracket couple. To control 2nd-order effects on the molar, a rigid .019" × .025" stainless steel wire was placed passively from the molar tube to the miniscrew slot and affixed with composite resin (Fig. 19C). Thus, the counterclockwise moment on the molar was minimized through indirect reinforcement by rigid anchorage to the miniscrew (Fig. 19D). After four months, the canine had extruded significantly while the buccal segment was unchanged. At this stage, an .017" × .025" CNA intrusion arch was placed, and the indirect anchorage from the miniscrew was continued to control 2nd-order effects on the molar (Fig. 19E).

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Figure 20 A. Placement of uprighting spring anchored by miniscrew for correction of mesially tipped lower right first and second molars in 23-year-old male patient after orthognathic surgery. B. Two months later, archwire segmented to localize moment to posterior segment. C. Force diagram of clinical setup. D. Two months after archwire segmentation, significant improvement noted.
Fig. 21 A. Placement of miniscrew distal to lower right first premolar as direct anchorage for closure of edentulous second-premolar space in 28-year-old female patient. B. Initial placement of cantilever anchored to same miniscrew for transverse correction of mandibular arch. C. Pretreatment (yellow) and predicted (gray) dental positions, illustrating anticipated effects from cantilever. D. Patient after four months of treatment, showing improved arch coordination.
generated by the intrabracket couples, especially at the first molar. The next treatment option was to increase the counterclockwise moment on the posterior dentition by adding an uprighting spring. The concern was that using the anterior dentition for anchorage would result in an intrusive force on this segment and thus open the bite considerably, especially since lighter nickel titanium wires were in place rather than a rigid stainless steel base archwire. To avoid such side effects, direct skeletal anchorage was proposed. A 2mm × 9mm LOMAS miniscrew was placed through the buccal cortex between the lower right canine and first premolar. An uprighting spring was fabricated from .017" × .025" CNA, with a helix placed adjacent to the molar to generate a large moment. The uprighting spring was engaged in the auxiliary tube of the molar and stabilized at the miniscrew, using a loop for single-point contact (Fig. 20A). The spring was not inserted in the miniscrew slot because it would have generated an undesirable moment at the screw. An elastomeric chain was placed to prevent space from opening between the first molar and first premolar. Two months after initial activation, only minor posterior improvement was noted (Fig. 20B). To localize the moment to the posterior segment, the base archwire was then segmented mesial to the first molar. This produced a counterclockwise rotation of the first-and-second-molar segment, while the anterior segment was corrected vertically with intermaxillary elastics (Fig. 20C). Two months later, the inclination of the first molar had improved significantly (Fig. 20D). At this point, with the lower arch leveled, a straight wire was placed to detail the occlusion and close the residual space from the molar uprighting.

Three-Dimensional Applications of One-Couple Systems

An additional advantage of combining one-couple systems and skeletal anchorage is the potential to correct multiple dimensions simultaneously with a single miniscrew. Figure 21A shows a 28-year-old female whose lower right second premolar had been previously extracted. To close the edentulous space, a buccal 2mm × 7mm LOMAS miniscrew was placed distal to the first premolar as direct anchorage for protraction of the first molar. Two infrazygomatic screws had been inserted earlier for maxillary molar intrusion to correct the patient’s open bite. While significant bite closure had been achieved, the canting of the mandibular arch had not improved and was contributing to a persistent lateral open bite on the left side. In addition to the vertical problem, the mandibular arch was also skewed enough that the crowns of the right posterior teeth were tipped lingually, causing a Brodie bite. Since the lower-molar protraction was nearly complete, the plan was to utilize the miniscrew to provide a buccal force for correction of the transverse problem. An .017" × .025" CNA cantilever was inserted in the miniscrew slot and extended to a contact point on the base archwire distal to the lateral incisor (Fig. 21B). The setup was again a one-couple system, with the moment acting on the miniscrew and the force applied to the entire mandibular arch by means of an .017" × .025" stainless steel archwire (Fig. 21C). This force skewed the mandibular arch in the axial plane, reducing the canine overjet and correcting the dental midline. Four months later, note the improvement in the mandibular cant and the closure of the lateral open bite, as well as the transverse correction (Fig. 21D).

Controlling Torsional Forces on Miniscrews

As previously mentioned, placement of a miniscrew perpendicular to the long axis of the dentition—in the buccal cortex, for example—can result in counterclockwise or clockwise torquing moments on the miniscrew and potentially lead to screw failure. There are a number of ways to counteract this problem, including placement of the miniscrew in line with or parallel to the dentition. Figure 22A shows an adult female referred by her prosthodontist for limited orthodontic treatment. The objectives were to close the spacing in the maxillary arch and correct the supraeruption of the lower left second premolar, thus providing interocclusal space for the placement of maxillary implant restorations. Since the patient wanted min-
imal fixed appliances, the plan was to intrude the second premolar using miniscrew anchorage. Significant force would be required to intrude the tooth, but insertion of the miniscrew into the buccal cortical plate would result in a significant torsional moment, potentially loosening the miniscrew. The lower left first molar was periodontally compromised and deemed nonrestorable. After this tooth was extracted (Fig. 22B), the edentulous space was adequate for placement of a miniscrew in the alveolar ridge, parallel to the second premolar. In this configuration, the moment on the miniscrew would be resisted by the long axis of the screw as well as the screw head (Fig. 22C). A 2mm × 7mm LOMAS miniscrew was inserted distal to the second premolar, with composite added to the abutment to allow a more gingival bracket positioning compared to the premolar bracket. An .017" × .025" CNA wire segment was placed in the miniscrew bracket slot and ligated above the premolar bracket to increase the vertical activation (Fig. 22D). Three months later, the second premolar had been intruded to the level of the first premolar (Fig. 22E). The miniscrew was then re-

**Fig. 22** A. Adult female patient with overextruded lower left second premolar and periodontally compromised first molar before treatment. B. After extraction of lower left first molar. C. Forces acting along long axis of miniscrew placed in edentulous alveolar ridge. D. Clinical setup for intrusion of second premolar. E. After three months of intrusion, second premolar level with first premolar.
Fig. 23  A. 51-year-old female patient with two buccal miniscrews inserted as anchorage for intrusion of overextruded upper second molar. B. Miniscrew assembly in place. C. Force diagram of clinical setup. D. Transpalatal arch placed for transverse control during molar intrusion. E. Six months later, second molar intruded significantly without buccal tipping.
moved, the first premolar was bracketed, and a rigid stainless steel wire was placed between the premolars for retention until the maxillary restorations could be carried out.

The method illustrated in Figure 22 is ideal for a case in which an edentulous space provides sufficient room for placement of a miniscrew over the alveolar ridge and in line with the dentition. If such space is not available and the miniscrew still needs to be placed perpendicular to the long axis of the dentition, the intrabacket couple (generated by the V-bend in a one-couple system) can be controlled by two miniscrews to reduce the possibility of screw failure. Figure 23A shows a 51-year-old female requiring intrusion of the upper left second molar in preparation for an implant restoration in the mandibular arch. The plan was to intrude the second molar with a miniscrew-anchored cantilever prior to placement of a continuous wire in the maxillary arch, thus avoiding an extrusive side effect on the first molar. Two 1.6mm × 8mm LOMAS miniscrews were inserted in the buccal cortex mesial to the first molar, after radiographic confirmation that the mesial-in rotation of the first molar would allow enough space for both screws. In this configuration, the two miniscrews could be joined as a unit to resist the torsional moment generated by the cantilever. An .036" × .072" sheath was embedded in an acrylic matrix for indirect placement of the cantilever, which was fabricated from .032" stainless steel wire as previously described. The cantilever was inserted through the lingual sheath of the miniscrew assembly and attached to the second molar with stainless steel ligature wire (Fig. 23B). Thus, the intrabacket couple would consist of two equal and opposite forces within the sheath, theoretically exerting a single linear force on each miniscrew and reducing torsional forces (Fig. 23C). Since the miniscrew assembly was buccal to the center of resistance of the molar, however, there was a potential for buccal tipping of the molar during intrusion. A transpalatal arch was therefore placed to control any undesirable transverse effects (Fig. 23D), while the lingual component of the intrusive force would counteract buccal movement of the molar. Six months later, the second molar was level with the first molar, and no unwanted buccal tipping of the second molar was evident (Fig. 23E).

The last case further illustrates this concept. A 66-year-old female presented for forced extrusion of the upper left canine prior to a crown restoration (Fig. 24A). Since she did not desire comprehensive orthodontic treatment, the objective was to utilize direct miniscrew anchorage to achieve single-tooth extrusion without any side effects on the well-restored dentition. Two 2mm × 7mm LOMAS miniscrews were placed mesial to the upper left first molar. The second premolar was replaced by a pontic as part of a three-unit bridge.
from first premolar to first molar. An .017" × .025"
CNA cantilever with an extrusive gable bend was
made to fit passively between the miniscrew slots
and ligated to the canine bracket. Again, rather
than generating the intrabracket couple that is usu-
ally created by a point contact on the mesial and
distal edges within the bracket, this system di-
vided the couple into two separate and opposite
linear forces, one for each miniscrew (Fig. 24B).
Each force component of the couple was thus re-
sisted by a corresponding miniscrew, avoiding the
production of a torquing moment on a single screw
head. Figure 24C shows the patient three months
later, evidencing significant canine extrusion.

Conclusion

This article has discussed various applica-
tions of one-couple systems using miniscrew
anchorage. The main advantage is the ability to
use predictable force systems while deflecting any
side effects away from the dentition. To reduce the
potential for miniscrew failure, the key is to min-
imize torquing moments on the screw head.

We have highlighted the clear benefits of
using these methods for complex corrections of sin-
gle teeth, segments of teeth, or entire arches with
little to no effect on the surrounding dentition. By
understanding the concepts of these basic force
systems, the clinician can provide targeted treat-
ment that is both predictable and efficient.

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REFERENCES

18. Leung, M.T.C.; Lee, T.C.K.; Rabie, A.B.M.; and Wong,
R.W.K.: Use of miniscrews and miniplates in orthodontics, J.
19. Zawawi, K.H.: Acceptance of orthodontic miniscrews as tem-
20. Papageorgiou, S.N.; Zogakis, I.P.; and Papadopoulos, M.A.: 
Failure rates and associated risk factors of orthodontic mini-
screw implants: A meta-analysis, Am. J. Orthod. 142:577-595,
2012.
21. Papadopoulos, M.A.; Papageorgiou, S.N.; and Zogakis, I.P.: 
Clinical effectiveness of orthodontic miniscrew implants: A 
factors for the success of orthodontic mini-implants: A sys-
23. Crismani, A.G.; Bertl, M.H.; Celar, A.G.; Bantleon, H.P.; and
Burstone, C.J.: Miniscrews in orthodontic treatment: Review
and analysis of published clinical trials, Am. J. Orthod.
24. Topouzelis, N. and Tsaousoglou, P.: Clinical factors correlat-
ed with the success rate of miniscrews in orthodontic treat-
25. Costa, A.; Raffaiani, M.; and Melsen, B.: Miniscrews as ortho-
torque of miniscrews used for orthodontic anchorage: A pre-
liminary report, Int. J. Oral Maxillofac. Impl. 21:283-289,
2006.
Orthodontics, Mosby, St. Louis, 2009.
28. Uribe, F.; Janakiraman, N.; Fatal, A.N.; Padala, S.; and
Nanda, R.: A biomechanical approach to second-molar intru-