KD loop for increasing arch perimeter in cleft and noncleft cases

Kartik D. Dholakia, BDS, MDS¹
Shweta R. Bhat, BDS, MDS²

One of the many indications for dental arch expansion in treating malocclusion is to achieve arch compatibility, especially in surgical cases with severe Bolton discrepancies or collapsed arches due to congenitally missing anterior teeth. These cases usually require expansion in both the sagittal and transverse plane to achieve normal arch compatibility. Arch compatibility can be achieved by either dentoalveolar or skeletal expansion or both. Orthodontically, dentoalveolar expansion can be achieved by means of expanded arch form, vertical loops, or an added assembly such as a quad helix or Ni-Ti expander from the palatal or lingual aspect of the arch. However, these modalities normally provide expansion along transverse plane. If any expansion along sagittal plane is required, then additional appliances such as TransForce or modifications in the appliance system (eg, a quad helix with extension on anterior teeth) are necessary. Vertical loops do overcome these drawbacks to a certain extent; however, at the expense of generating moments during preactivation, which may lead to tipping of segments adjacent to the loop and precludes its use for larger changes of arch dimension. This article describes a new loop design—the KD loop—that increases the arch perimeter by sagittal and transverse expansion without generating significant moments along vertical plane. ORTHODONTICS (CHIC) 2012;13:e140–e152.

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A major portion of the treatment rendered to correct malocclusion is concerned with transverse and sagittal crowding of teeth, dentoalveolar protrusion, and the need to alter the facial profile. Correction of such malocclusions requires creation of space. One modality to achieve this is arch expansion, which is the most conservative form of treatment.⁷ Apart from the indications for arch expansion mentioned above, one more indication that requires arch expansion is achieving arch compatibility, especially in surgical cases with severe Bolton discrepancies or collapsed arches due to congenitally missing anterior teeth (eg, a collapsed mandibular arch due to congenitally missing mandibular central incisors). In patients with oral clefts due to retrognathic and contracted maxillary arches, obtaining compatibility among the maxillary and mandibular arches is among the major concerns to obtain proper surgical correction. These cases usually require expansion in both the sagittal and transverse planes to achieve normal arch compatibility.²,³

Arch compatibility can be achieved by dentoalveolar or skeletal expansion or both. Orthodontically, dentoalveolar expansion can be achieved with expanded arch forms, vertical loops, or an added assembly such as a quad helix or nickel-titanium (Ni-Ti) expander from the palatal or lingual aspect of the arch.
However, these modalities usually provide expansion along transverse plane. If any expansion along sagittal plane is required, it requires use of additional appliances or modifications in the appliance system. Vertical loops do overcome these drawbacks to a certain extent, but at the expense of generating moments during preactivation, which may lead to tipping of segments adjacent to the loop and precludes its use for larger changes in arch dimensions.4,5

This article describes a new loop design—the KD loop—that leads to an increase in arch perimeter by sagittal and transverse expansion, while minimizing significant moments along vertical plane that may arise while using other loop designs.

**DESIGN**

The loop design consists of two pairs of helices (two each along the vertical and horizontal planes) that are positioned diagonally to each other in relation to the connecting wire, which is termed diagonal.

The archwire fabrication requires use of 0.017 × 0.025-inch or 0.019 × 0.025-inch beta-titanium alloy (TMA) archwire (the case reports below explain the rationale behind using heavier wires in cleft cases). Each helix should have an internal diameter of approximately three times the thickness of the wire.

The rationale for using TMA wire:

- Resilient as compared with stainless steel
- Stiffer than Ni-Ti, which maintains control over tooth inclinations and delivers enough force for transverse expansion
- Prevents deformation of the wire during forceful engagement in the bracket slots, which would otherwise occur with stainless steel wire

The distance between the incisal edge and bracket slot is measured (denoted as x) for the teeth adjacent to the site where loop is to be positioned, so that the completed loop (which measures 2x along vertical plane) does not project beyond the occlusal plane (Fig 1).

For the formation of helices, either Tweed loop-forming pliers or bird's beak pliers may be used. The second step of the cylindrical beak of the Tweed loop-forming pliers can be used to fabricate the helices. The archwire fabrication starts with the formation of helix 2 (see Fig 1). The two legs of the wire should be now parallel (note that the mesial leg should be labial to that of distal leg). Next, helix 3 is fabricated on the distal leg, such that the distance between helices 2 and 3 is double the distance of x. Helix 3 should be made such that the distal leg of helix 3 is now labial to its mesial leg. The portion of the wire connecting the helix 2 and 3 is called the major diagonal, since the two helices on the ends of this portion are in diagonally opposite sides/directions.

Helices 1 and 4 are made in similar manner, but at a distance of x from helices 2 and 3, respectively. The orientation of the helix along buccolingual plane should be opposite to that of the adjacent helix (ie, the buccolingual orientation of helices 1 and 3 would be the same and opposite to that of helices 2 and 4). The archwire is then bent at helices 1 and 4 such that both the free ends of the wire are along the same horizontal plane. The portion of the wire connecting helices 1 to 2 and 3 to 4 is called the minor diagonal. (Note that the buccolingual orientations of the helices may be changed to prevent any gingival impingement.) At this stage, the legs of each helix are parallel to each other and perpendicular to horizontal extensions. The distance between helices 1 and 4 should be approximately 8 mm. After complete compression of loop, the distance between helices 1 and 4 should be about 4 mm. Therefore, an in-built
activation of 4 mm would be present only if the loop is completely compressed. With practice, fabrication of the four helices with the configuration mentioned above does not take more than 5 minutes.

The activation of the wire is done at this stage by opening helices, such that the free ends of the wire are along same horizontal level. The amount of activation for helices 2 and 3 should be relatively larger than helices 1 and 4, and helix 3 (the gingival helix) be slightly more than helix 2 (because while the archwire is engaged, helix 3 is closer to tooth’s center of resistance than helix 2 and helix 3 needs to generate slightly larger moments than helix 2 to minimize vertical moments in relation to the center of resistance). The amount of activation is determined as follows: distance between helices 1 and 4 = amount of space required + 2 mm of overactivation – amount of built-in activation.

Built-in activation would occur only when the interbracket distance is less than that of the nonactivated loop dimensions, ie, 8 mm (for example, in the mandibular anterior region, where interbracket distance is less than 8 mm). If a space needs to be opened by 5 mm, activation of the helices should be performed such that the distance between the helices 1 and 4 would be 15 mm (8 mm loop dimension + 5 mm of space required + 2 mm of overactivation). In cases in which a large amount of space needs to be reopened, activation should be made in stages. Considering the amount of overactivation (approximately 2 mm), one-time activation of more than 15 mm (of the distance between helices 1 and 4) should be avoided. The rationale for this being is that with high amounts of activations (with horizontal sections of the wire kept along the same horizontal plane), when the wire is placed in its pre-activated state, the vertical level of the horizontal section of the archwire on either side of the loop will be different (though parallel to each other) (Fig 2). The amount of activation should also depend on the periodontal condition and type of tooth adjacent to the loop.

Fig 1 Design and components of the KD loop. (a) Fabrication of helix 2, (b) helix 3, (c) helix 1, and (d) helix 4. (e) Completed KD loop configuration. Arrows indicate the direction of wire bending along its length.
After activation of the loop assembly, contour the archwire as per the desired arch form (not the patient’s existing contracted arch form), which is expanded enough to achieve arch compatibility with the opposing arch. Some amount of overexpanded arch form (perhaps 1 to 2 mm on either side in the canine and/or molar region) may be incorporated, depending on the initial degree of arch contraction. The total time required for loop fabrication, activation, and formation of arch form usually takes 15 to 20 minutes. The archwire is then engaged in the brackets adjacent to the site of placement of the loop, with stainless steel ligature wire, followed by ligation to the adjacent teeth (Fig 3).

Patients should be recalled after 1 month. In cases of persistent alveolar cleft, the recall schedule should be shorter (15 to 20 days). Due to the absence of alveolar bone continuity, the minor cleft segment also shows some orthopedic displacement along with dentoalveolar tooth movements and may cause changes to occur faster in these patients. In noncleft patients, such force levels (as delivered by the KD loop) are unlikely to result in significant orthopedic effects in adolescents or adults.

**BIOMECHANICS**

**Functions**
The functions of helices 2 and 3 are to counteract moments generated during activation of loop and to store energy for opening space and increasing arch width.

Helices 1 and 4 dissipate stress at the junction of horizontal section and the loop, which would otherwise develop in the absence of helices 1 and 4, leading to permanent deformation at this junction (this will lead to inadvertent generation of moments and associated drawbacks). They are diagonally opposite to
counteract moments generated during activation of loop and enable larger activations to be built in.

The major diagonal helps transmit transverse force for arch width augmentation and creation of space. Upon forceful engagement in the bracket slot, the minor diagonal transmits the forces to helices 2 and 3, along with anterior labial/buccal deflection of helices 2 and 3 and the major diagonal (see Fig 3), which results in an increase in arch length by proclination of the anterior teeth (if loop is placed in anterior region) and varied amount of arch width increase by buccal movement of the neighboring teeth (if loop is placed eccentrically).

**Vertical plane**
In this loop design, the helices 2 and 3 and 1 and 4 are in diagonally opposite sides of the wire. Therefore, on flexion along the helices/or on preactivation, the moments produced on relaxation of these helices would cancel out while opening the space. Since the point of force application is away from center of resistance of the teeth adjacent to the loop, some distal tipping of the teeth adjacent to the loop may be anticipated. This can be counteracted by adding some counter moments of about 5 to 10 degrees by incorporating gable bends at the end of helices 1 and 4 (Fig 4).

**Transverse plane**
Along with the opening of the space, there will be an increase in arch width, in addition to an increase in the arch length due to the proclination of the anterior teeth. The magnitude of increase in arch width depends upon the location of the loop and shape of the arch form. Anterior loop position would favor relatively larger increases in arch width with space reopening in the anterior region, while posterior positioning would favor an increase in arch length (Fig 5).

**Force**
One may feel that an activated loop may deliver too much force. This is not true, though, provided that there is no space distal to the teeth between which the loop is placed, because the force of the loop will be dissipated over all the teeth (through contact points) on either side of the loop as they are consolidated. The teeth adjacent to the loop will definitely have to bear relatively larger forces, but not as high as one may anticipate. However, the force vectors are straight lines and cannot be precisely routed around the arch curvature. Therefore, the teeth adjacent to the loop will experience some proclining force (as the point of force application is labial/buccal to the center of resistance), which will not get completely counteracted, even by consolidation of the seg-

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**Fig 4** Biomechanics along vertical plane, showing clockwise (green-headed arrows) and counterclockwise moments (red-headed arrows).
ments and clinching of the archwire distal to the molars. However, if there is any space available for distal movement of teeth (adjacent to the loop), the archwire may be cinched so that the proclination of anterior teeth can be controlled until the loop pushes the adjacent teeth into that available space. Even with cinching the archwire, proclination of anterior teeth cannot be completely prevented, because the arch dimension increases radially outward in the incisor and canine regions, which are along the curvature of the arch. If there is no such space available, cinching the distal ends of the archwire will not minimize the proclination of the anterior teeth (Figs 5b and 5c).

It should be noted that rectangular archwires will have better torque control on molars and premolars, which may be enhanced with additional torque via a transpalatal arch or simply incorporated in the archwire. In cases in which the buccal root torque is not required, a round archwire may be used.
CASE REPORTS

Unilateral cleft lip and palate
These patients (patients 1 and 2; Figs 6 and 7, respectively) exhibited alveolar cleft on the left side of the maxillary arch with a history of primary palatal repair and no history of alveolar bone graft treatment. Both patients exhibited normal to mildly increased maxillary intermolar width, with narrower interpemolar and intercanine width. Arch length was also reduced. In both patients, it was planned that maxillary advancement would be performed by distraction osteogenesis and mandibular setback by orthognathic surgery (bilateral sagittal split osteotomy). Initial tooth alignment using thermal Ni-Ti archwires (0.016 to
0.017 × 0.025-inch) was carried out with care to maintain distal inclination of the roots of the teeth adjacent to the alveolar cleft. However, it was observed that when the casts were articulated with predetermined positions to achieve the best possible occlusion (assuming maxillary advancement and mandibular setback surgery), the arch compatibility was unacceptable, with crossbite in the premolar, canine, and incisal regions (Figs 8 and 9). Intermolar widths, however, were coordinated (patients with oral clefts have normal to increased intermolar widths). To achieve arch compatibility, the maxillary arch required expansion in the premolar and canine regions (more in the canine region), along with proclination of the anterior teeth.
Therefore, the KD loop with eccentric placement in the cleft site was planned to gain space in the cleft region, along with an increase in arch length (by proclination of the anterior teeth) and in arch width (in the premolar and canine region). It should be noted that 0.019 \times 0.025\text{-inch TMA archwire was preferred to 0.017 \times 0.025\text{-inch archwire, because the larger archwire delivered relatively heavier forces to displace the minor segment of the cleft laterally, along with dentoalveolar changes (all the teeth on either side of the cleft site were consolidated using a figure-eight ligature tie). Activation of 7 mm (resulting in initial force of up to 300 g) was done for both patients 1 and 2. In patient 2, additional gable bends of approximately 10 degrees was made on both ends to correct the dumping of segments into the cleft site (which led to uneven maxillary occlusal plane and lateral open bite, probably due to an adaptive lateral tongue thrust). Force levels were measured by compressing the loop outside the oral cavity. When the archwire was inserted, the force borne by the adjacent teeth due to the compressed loop will be lesser, as the archwire is engaged in the buccal segments, thereby taking some of the load from the compressed loop, which results in arch development along the transverse plane.

To maintain intermolar width and prevent any buccal tipping of molars, additional buccal root torque was applied by means of the transpalatal arch.
Results
Patient 1 (Fig 8). After 21 days, the space had reopened by 5 mm. Study casts were obtained at this time. When the study casts were articulated with a predetermined position to simulate occlusion postsurgery (as described above), reasonable arch compatibility could be achieved with an overjet of 1.5 mm and proper buccal occlusion in the canine, premolar, and molar regions.

When comparing the study casts (made before and after placement of the KD Loop), it was observed that arch length increased by 3.5 mm, arch width increased by 3 mm in the canine region and 2 mm in premolar region, and 5 mm of space was gained in the cleft site. Figures 10e to 10g (2 1/2 months postsurgery) show interarch compatibility after surgical advancement of the maxillary and mandibular setback. The space between the incisors was closed again postsurgically by Class III elastics, while maintaining the transverse dimension (for arch compatibility) to achieve Class II molar relationships and proper occlusion with the maxillary left premolar (to be considered as a canine) with the mandibular left canine and the maxillary left canine to be recontoured as a lateral incisor.

Patient 2 (Fig 9). After about 40 days, the space in the cleft site was opened by 4 mm. It was observed that when the study casts were articulated with predetermined positions to simulate occlusion postsurgery, reasonable arch compatibility could be achieved with an overjet of 1.5 mm and proper buccal occlusion in the canine, premolar, and molar regions.

On comparing study casts (made before and after placement of the KD Loop), it was observed that the arch length increased by 4.5 mm, arch width increased by 3 mm in the canine region and 2 mm in premolar region, and 4.5 mm of space gained in the cleft. Additionally, the occlusal plane of maxillary dentition on either side of the cleft site was reasonably leveled, which was due to lateral tipping of the dentition on either side of the cleft site, coupled with some amount of distal tipping of minor segment (may be some amount of extrusion of teeth).

In patients with severe alveolar clefting extending to palate with variable extent (and in absence of bone continuity in alveolar region), with moderate amount of digital pressure, the minor segment will seem to be mobile. Therefore, it was not surprising to observe the distal and lateral tipping of the minor segment.

In both the patients, due to placement of transpalatal arch with buccal root torque, no further loss of buccal root torque was observed, and the intermolar width was maintained.

In oral cleft patients, where alveolar bone continuity is established by bone grafts, the force level needs to be reduced. If higher force levels are used, it will be borne by the teeth (and may be detrimental), rather than getting dissipated in mobilizing the minor cleft segment, as it does in absence of alveolar bone continuity.

Mandibular arch
A 12-year-old boy (patient 3; Fig 10) reported with the chief complaint of protruding maxillary anterior teeth, a convex face, and congenitally missing mandibular central incisors. Phase 1 of treatment with twin block therapy was completed to correct the Class II skeletal relationship. Following this, fixed mechanotherapy was initiated. However, even with an Angle Class I molar relationship, a Class I canine relationship was not attainable due to congenitally missing mandibular central incisors. Also, the buccal occlusion in the canine and premolar was not satisfactory due to a lingually tipped mandibular dentition. The overjet and overbite was moderately increased, owing to collapse of the arch because of congenitally missing mandibular central incisors. There was 2 mm of space between the mandibular incisors and canines.
To achieve arch compatibility, a KD loop (made of 0.017 × 0.25-inch TMA) was planned for the mandibular arch (to be placed between the lateral incisors), featuring:

- Mild gable bends (5 degrees) were added near helices 1 and 4 to prevent distal tipping of the lateral incisors.
- Mild bite opening curves (2 to 3 mm) were added in canine-premolar region.
- Loop activation of 7 mm (resulting in initial force levels of up to 200 g), including built-in activation (as the interbracket distance was slightly smaller than the distance between helices 1 and 4).
Force levels were measured by compressing the loop outside oral cavity. When the archwire is inserted, the force borne by the adjacent teeth due to compressed loop will be lesser, since the archwire is also engaged in the buccal segments, thereby taking some of the compressed loop load, which results in arch development along the transverse plane.

An 0.017 × 0.025-inch TMA was preferred to the 0.019 × 0.025-inch, so as to deliver relatively lesser forces on the mandibular dentition (especially the mandibular lateral incisors) to reopen space for the central incisor and allow buccal tipping of the posterior teeth and proclination of the anterior teeth. Also, with the use of 0.017 × 0.025-inch archwire in the 0.022-inch slot provided additional play between the bracket slot and archwire in the premolar and molar region to allow buccal uprighting.

Results
After 1 month, study casts (Fig 11) were made to check for arch compatibility. The following objectives were achieved:

- Space of 4.5 mm was gained for prosthetic replacement of one central incisor
- Proper buccal occlusion in the canine and premolar regions
- Class I canine relationship
- Proclination of the mandibular anterior teeth to achieve an increase in arch length as well as near normal overjet and overbite
- Moderately leveled curve of Spee

Following this, a riding pontic of suitable size (to maintain the space for the prosthesis) was placed along with a 0.019 × 0.025-inch Ni-Ti and then a 0.019 × 0.025-inch stainless steel archwire. After debonding, an Angle Class I molar relationship with Class I canine relationship was observed.

In all three cases, the teeth adjacent to the loop were found to be vital after removal of the loop.

Table 1 summarizes changes in the arch dimensions in all patients following placement of the KD loop.

| Table 1 Changes in the arch dimensions (mm) in all patients following placement of the KD loop |
|---------------------------------------------|---------------------------------------------|---------------------------------------------|
| Arch treated using the KD loop              | Patient 1                                  | Patient 2                                  | Patient 3                                  |
| Treatment duration                          | 21 d                                       | 40 d                                       | 35 d                                       |
| Increase in arch width                      |                                            |                                            |                                            |
| Canine region                               | 3                                          | 3                                          | 3.5                                        |
| First premolar region                       | 2                                          | 2                                          | 2                                          |
| Second premolar region                      | 1.5                                        | —                                          | 1.5                                        |
| First molar region                          | —                                          | —                                          | —                                          |
| Arch length increase                        | 3.5                                        | 4.5                                        | 2                                          |
| Space gained in site of loop placement      | 5                                          | 4.5                                        | 4.5                                        |
ALTERTNATIVE TREATMENT PLAN

In the case reports outlined above, an alternative treatment could have been suggested, including vertical/U loops in the archwire, use of an open coil spring, and use of an additional palatal expander such as the quad helix or Ni-Ti expander.

The KD loop design was chosen for the following reasons. This new design was preferred for achieving arch expansion in both the sagittal and transverse plane while creating space for the prosthesis. This was achieved without any need for archwire adjustments or activations. Also, in patient 2, despite the presence of vertical discrepancies between the dentition on either side of the cleft, it was feasible to engage the archwire. In addition to accomplishing the above-mentioned objectives, it also achieved leveling of the maxillary dentition with the help of gable bends. The loop also allowed for placement of TPA in patients 1 and 2 to control intermolar width and provide additional buccal root torque. The above-mentioned alternative methodologies, when employed individually, would have helped achieve some objectives, but not all at once. To do so, these alternative methodologies would have also required additional adjustments and/or accessories (such as palatal expanders), all of which could have added toll to inventories and the treatment time.

For patient 3, the main criteria for selecting this loop design was to promote an increased arch width by allowing buccal uprighting of canine-premolar segment (while maintaining the intermolar width) along with creation of space for the prosthesis, proclination of anterior teeth, and leveling of the curve of Spee. This helped to obtain an Angle Class I molar relationship and Class I canine relation with reduction in overjet and overbite.

Also, if proclination of the anterior teeth needs to be controlled, the archwire can be cinched distally of the molars.

CONCLUSION

The quest to simultaneously increase arch dimensions along the transverse plane and sagittal plane, create space for prostheses, and level the arches without using any additional appliances led to the development of this loop design. The main aim was to minimize the moments generated along the vertical plane by the loop assembly in its activated state, so as to better anticipate the treatment outcome along all three planes of space. The new loop design worked successfully in three patients. However, the amount of activation and forces produced needs to be judged by the clinician, rather than adhering to the absolute values mentioned above. Similar results may be obtained by other techniques, as well. This loop design provides an additional method to achieve the desired treatment objectives.

REFERENCES