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REVIEW ARTICLE

CANINE DISIMPACTION SPRINGS THROUGH THE AGES

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ABSTRACT

Orthodontic management of impacted canines can be a very complex and requires a carefully planned interdisciplinary approach. The surgical orthodontic treatment of impacted canines is aimed at bringing the tooth into its correct position in the dental arch without causing periodontal damage. Various forms of inter-arch and intra-arch mechanics have been developed for the eruption of impeded and impacted teeth. The availability of newer materials with variable modulus and variable transition temperature has stimulated the development of various appliances designs with newer materials and configurations for alignment of impacted canines.

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INTRODUCTION

Impacted teeth are those with a delayed eruption time or that are not expected to erupt completely based on clinical and radiographic assessment. (Thilander and Jakobson, 1968) Permanent maxillary canines are the second most frequently impacted teeth; the prevalence of their impaction is 1-2% in the general population. (Rayne, 1969; Bass, 1967) This is most likely due to an extended development period and the long, tortuous path of eruption before the canine emerges into full occlusion. (Rayne, 1969) Orthodontic management of impacted maxillary canines can be very complex and requires a carefully planned interdisciplinary approach. The surgical orthodontic treatment of impacted canines is aimed at bringing the tooth into its correct position in the dental arch without causing periodontal damage. The teeth are surgically exposed and moved towards the arch wire after the maxillary arch is stabilized by progressing to a rigid arch wire. To achieve this goal, a variety of surgical and orthodontic techniques have been proposed both in relation to the position of the impacted tooth and to the ligation technique used. (Fournier *et al.*, 1982; Davies and Gray, 2001) Getting the canine tooth into occlusion helps to establish a proper canine guided occlusion. (Begg and Kesling1971).The availability of newer materials has stimulated the development of numerous kinds of appliance designs for alignment of impacted canines. Superelastic wires, elastic threads, and chain elastic have made preadjusted edgewise technique more efficient. (Jacobay, 1979; Crescini *et al.*, 1994; Kawata and Takeda, 1977; Darendeliler and Joho, 1992; Darendeliler and Fredili Marc, 1994; Becker, 2007; Samuels and Rudge, 1997; Ross, 1999; Sinha and Nanda, 1999; Burstone, 1962)

Ballista spring

Introduced by Harry Jacobay in 1979. Term Ballista was given by one of his patient as it reminded him of Roman Ballista. Made up of 0.014, 0.016 and 0.018 inch round SS wire which accumulates its energy by being twisted on its long axis. Its anchorage extremity penetrates in both headgear and edgewise vestibular tube of first and second maxillary molar thus preventing it to rotate in the tube giving a bi-dimensional stability. The horizontal portion of the wire accumulates the energy. This part of the wire is attached by a ligature on the first premolar, which allows it to rotate in the slot of the bracket as a hinge axis. The last part of the spring is bend down vertically and ends in a loop shape to which a ligature elastomeric thread can be attached. When the vertical portion of the spring is raised towards the impacted tooth, the horizontal part accumulates the energy into the twisted metal. When the vertical section is released, it bumps down like a "Ballista".0.016 inch wire provides an average force of 60-100 grams whereas 0.018 inch provides an average force of 120-150 grams for disimpaction. (Davies and Gray, 2001; Begg *et al.*, 1971)

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Tunnel traction

This technique introduced by Crescini *et al*. (1994) describes a surgical approach for the orthodontic treatment of deep infraosseous impacted canines. This technique allows for orthodontic traction of the impacted tooth to the centre of the alveolar ridge. A full thickness flap is raised to expose the cortical plate, and the deciduous canine is removed. Cortical bone is removed to provide access to the crown, and the follicular socket is eliminated. A low speed drill is inserted into the seat of deciduous tooth root to drill a perforation into the bone under careful cooling, to reach the crown of the impacted canine. The perforation and the deciduous socket forms a tunnel that is used for the traction. The chain of 1.5mm diameter is passed through the osseous tunnel and fixed as closely as possible to the cusp of the impacted canine by means of an attaching device. The flap is then repositioned and sutured again in its original seat. The chain passes through the bone tunnel and emerged from the socket of the deciduous tooth. A force of approximately 100 grams is applied and care is taken to maintain the chain at the centre of the socket. During the orthodontic traction phase, the eruption of the impacted tooth is guided through the tunnel, between the internal and external cortical plates. Thus the cusp of the impacted tooth emerges at the centre of the alveolar process, replacing the deciduous canine in the area surrounded by keratinized gingiva.

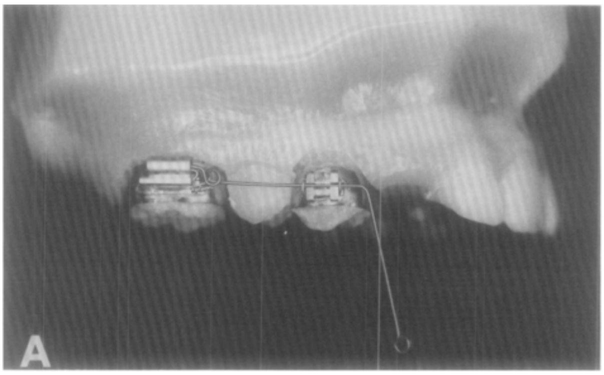


Fig. 1. The ballista spring, its anchorage and action. **A,** The ballista spring before activation. It is inserted in the molar tube and ligated in the first premolar bracket.

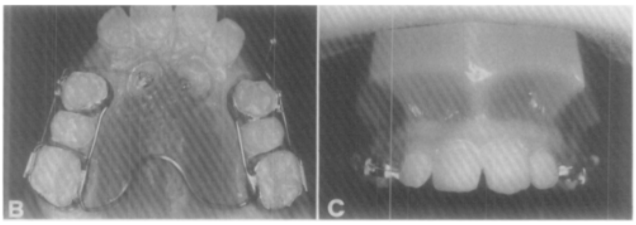


Fig. 1B and **C. B,** The anchorage for the ballista spring system. The transpalatal arch crosses the palate in the posterior region. The right spring is activated; the left one is free. **C,** By the lack of appliance on the front teeth, the esthetic side of the treatment is respected.

Magnets

Magnetic forces have been used in dentistry for very long time and Sandler and colleagues (Kawata and Takeda, 1977; Darendeliler and Joho, 1992) have reported use of magnets in the eruption of an impacted tooth. Darendeliler *et al*. (1994) used magnets in conjugation with fixed appliance therapy for canine disimpaction. After the permanent canine has been exposed after surgery a small magnet is bonded to the palatal surface of the canine, and the mucosal flap is sutured so that it completely covers the impacted tooth and the magnet. The patient is given a passive removable anterior plate to wear while the tissue healing takes place. Six days after surgery a samarium cobalt magnet 3mm×4mm×6mm is mounted on the removable plate 6.5 mm away from the bonded magnet. The initial force of the magnetic attraction is 10 grams. To free the path of eruption of the impacted tooth, a 9mm hole is cut in the acrylic. As the canine moves, the hole is enlarged. When the impacted canine and magnets can be seen directly under the palatal mucosa, the removable appliance is discontinued. A 2mm×3mm×5mm Samarium cobalt magnet is attached to a ballista spring sectional archwire which is then tied to the stabilizing arch. The eruption of the canine takes place in around ten months without any patient discomfort and satisfactory healing of the surrounding tissues.

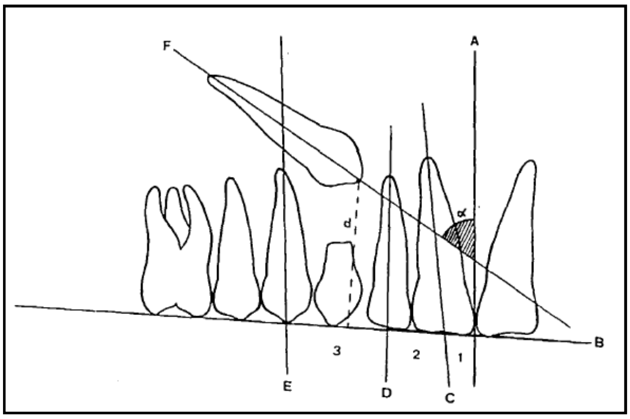


Fig. 2. Schematic drawing illustrates criteria used to define deep infraosseious impaction. The tracings are made on panoramic radiographs. The midline (A); the occlusal plane (from the first molar to the incisal edge of central incisor (B); the long axes of the central incisor, of the lateral incisor, of the first bicuspid, and of the impacted canine respectively (C), D(D), (E), and (F), the angle between F and A (α; the distance between the cusp of the impacted canine and occlusal plane (B) (d); the sectors where the cusp of the impacted canine can be located (1), (2), and (3)

Stainless steel Archwire Auxillaries (Becker 1995)

It is the most conveniently fashioned made up of 0.014 or 0.016 inch round stainless steel wire by forming a vertical loop in the area of the impacted canine. This loop has a small terminal helix. The auxillary is tied into all the brackets of the arch in a piggyback fashion over a heavy main archwire, with the extremeties slotted into a spare tube on the molars or left free distal to the second premolar bracket. In a similar manner to the ballista, the vertical loop is activated by raising it palatally across the canine space, and ensuring it in the pigtail ligatures in the palate. The auxillary labial wire draws its activation from the curved archform, which does not therefore transfer torque to the molar. This is a particular useful method for use with a bilateral impaction, when two different loops will need to be inserted into the archform. It is always recommended to use a base arch wire otherwise it causes extrusion of the adjacent teeth and alter the occlusal plane. Other loop auxillary also used frequently is an active palatal arch.

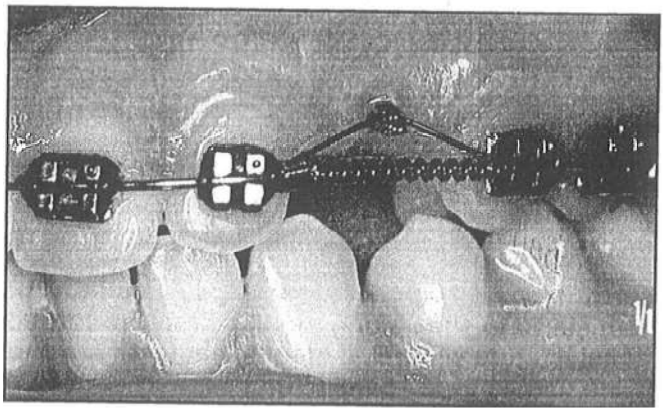


Fig. 3. Traction archwire deflected 3-4mm toward gold chain, with active and passive coil spring on main archwire maintaining space for unerupted tooth.

Two archwire technique

Samuels and Rudge (1997) introduced this technique of applying traction system to an impacted tooth using two nickel titanium archwires. 0.014 nickel titanium archwire is used for attachment to the gold chain which has been attached to the surgically exposed impacted tooth, and a main archwire is placed in the same bracket slot, over the traction archwire, for anchorage and control of the archform. The gold chain is trimmed to the occlusal level, leaving one or two links exposed. The traction archwire should be deflected 3-4mm towards the gold chain at the traction site and tied to the chain with a soft stainless steel ligature. Any normal sequence of archwire can be placed, but the 0.014" nickel titanium traction archwire should be kept in place until the impacted tooth has erupted in the oral cavity enough to bond a bracket to it. Thus the eruption of the tooth depends upon the super elastic properties of the traction archwire which slides underneath the main wire while leveling is carried out. Once the main archwire reaches the size of 0.019×0.025 stainless steel, the transpalatal arch can be removed and some expansion and torque can be placed in the molar regions of the main archwire. The opposing archwire can be treated simultaneously.

Nickel titanium closed coil spring

Loring Ross (1999) introduced the concept of attaching nickel titanium closed coil spring without end loops to be effective in patient with impacted canines. The eruptive force can be directly attached from the main archwire to a button or chain bonded to the impacted tooth. The end loops are eliminated because they reduce the effective amount of spring activation by 2-3 mm, and there is often only 3-4 mm between the stepped archwire and the canine attachment. To make that spring a 16 mm jones jig spring is cut into half and one of its end is pulled out slightly to form a small hook. Slip the hook through the link of elastomeric chain nearest to the gingiva and twist it a couple of times. Activate the spring and wrap several links around a stable rectangular archwire with an occlusal step. Be sure to leave a tail of chain for reactivation. A 0.009×0.041" spring provides 80 grams f force when stretched to twice its resting length. Unlike elastic thread showing a rapid decay, the nickel titanium spring delivers a light continuous force over a longer period of time. An impacted canine can be extruded enough to bond an attachment within six weeks.

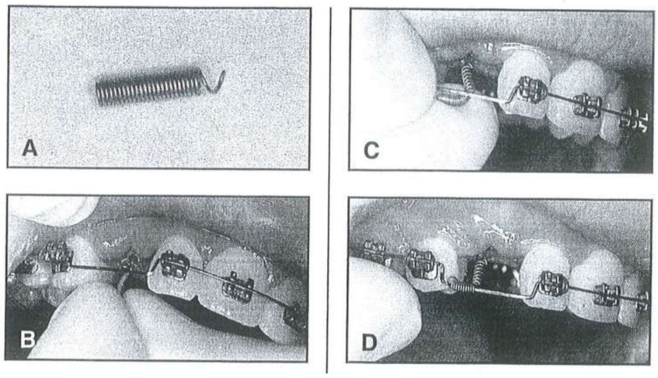


Fig. 4. Nickel titanium closed coil spring for extrusion of impacted canine

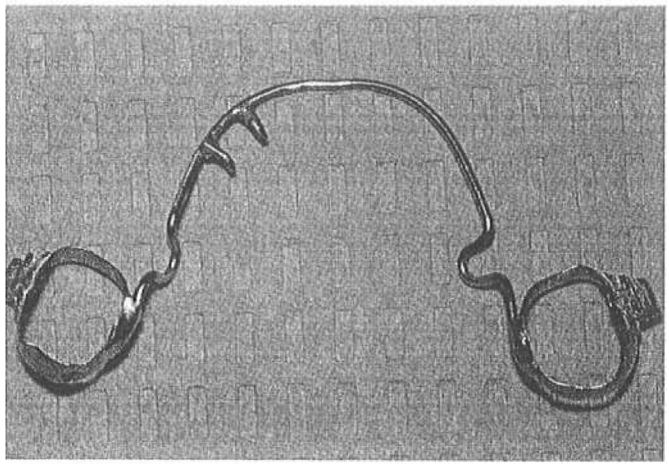


Fig. 5a Fixed lingual arch with soldered hooks

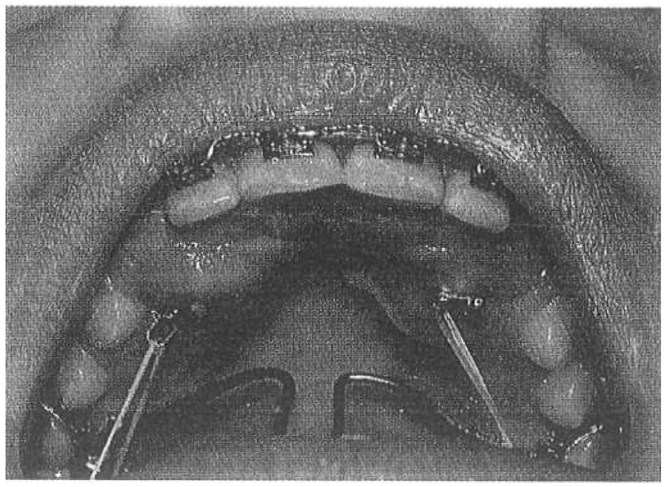


Fig. 5b. Elastic traction applied to bonded attachments

Mandibular anchorage

Pramod K Sinha (1999) introduced this technique using the mandibular arch as an anchorage unit to vertically erupt impacted maxillary canines. This technique utilizes a fixed lingual arch as opposed to a removable appliance. The lingual arch is prepared with vertical hooks bent in the arch during its fabrication before soldering, or hooks can be soldered to the arch for the same purpose. Elastics are engaged in this vertical hook and to the attachment on the impacted teeth for the traction required. In addition, directional forces can be used by applying elastics in a class II direction as required. Traction with light forces is applied in a range of 40-60grams based on the movement of the mandible.

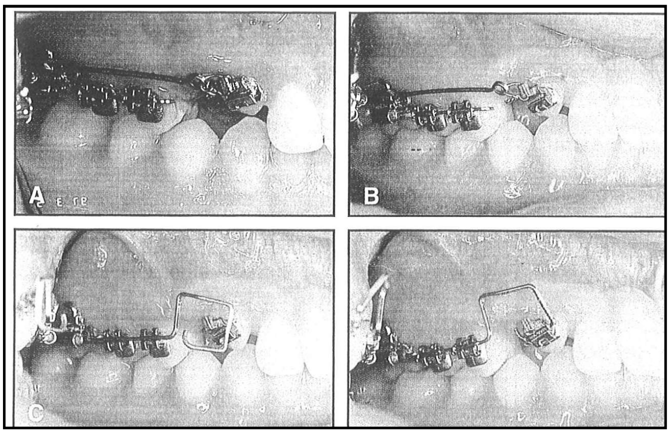


Fig.6 Cantilever and Box loop

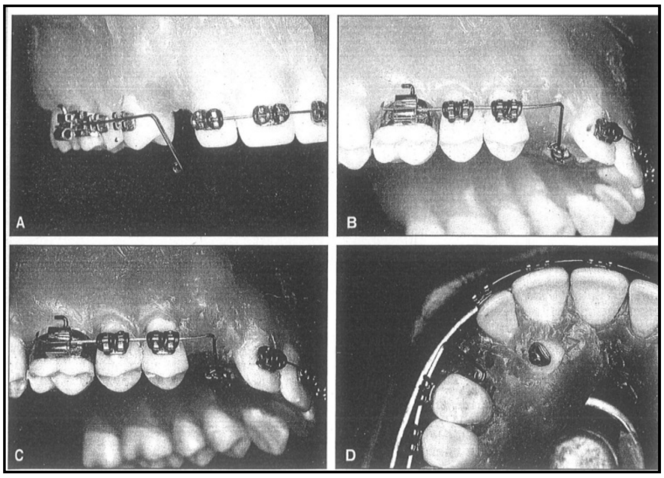


Fig.7. Activation of K-9 spring. A spring engaged in buccal segment. B. Vertical arm swung upward and ligated to bonded attachment on impacted canine. C. Spring cinched back about 2mm to provide force needed to distalize canine. D. Alternative activation method: bending vertical arm distally before ligating it to canine

Cantilever and box loop

Superelastic wires, elastic threads and chain elastics have made preadjusted edgewise appliance technique more efficient, while TMA wire has facilitated segmented arch technique. (Burstone, 1962) TMA cantilever springs have been used to extrude impacted canines as described by Lindauer and Issacson, (Samuels and Rudge, 1997) and the use of TMA box loops to produce first and second order correction while continuing vertical eruption. Segmented arch technique introduced by Burstone involves constructing a TMA cantilever spring made by 0.017×0.025" TMA wire which is inserted into the auxillary tube of first molar and connected by a one point contact to the active unit. The magnitude of force used to extrude the impacted canine should not exceed 70grams. The cantilever thus produces statistically determinate force system on the canine, with the appropriate magnitude and direction of force application. A box loop in contrast produces a statistically indeterminate force system when used for canine alignment. It is also fabricated with 0.017×0.025" TMA wire used to give first and second order bend after the canine is erupted in the oral cavity. (Ross, 1999)

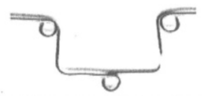
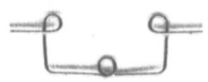
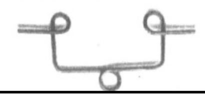
Archwire Design (.016")	Amount of Deflection (mm)	Force Delivery (g)
	0.5	110
	1.0	150
	1.5	215
	0.5	80
	1.0	140
	1.5	190
	0.5	120
	1.0	155
	1.5	210
	0.5	160
	1.0	225
	1.5	>250
	0.5	>250

Fig.8 Correlation between amount of deflection and force delivery

K-9 spring

K-9 sring introduced by Varun Kalra (1995) is made up of 0.017 0.025 TMA wire, which can be activated twice as far as stainless steel before it undergoes permanent deformation, while producing less than half the force. The horizontal arm of the spring is inserted into the first molar buccal tube and the premolar brackets. About 7 mm mesial to the first premolar bracket, the horizontal arm is bent 90^{o} downmard to form a vertical arm, which is about 11 mm long and ends in a helix. While the spring is held with a plier just diatal to the vertical arm, the vertical arm is bent about 20^{0} inwards, towards the plate. To activate the spring the vertical arm is swung upwards and ligated to the bonded attachment on the impacted canine. This provides a gentle extrusive force on the canine; the spring also has a buccal component of force due to its arcial pattern of activation and deactivation. The force needed to distalize the canine is achieved by cinching the spring back about 2 mm after it has been ligated to the canine. The K-9 spring is simple in design, low in cost and easy to fabricate. It also is comfortable for the patient requiring no special cooperation.

Australian helical archwire

Australian archwires are made up of austenitic stainless steel that has been heat treated and cold drawn down to a desired diameter to gain exceptional resilience, toughness and tensile strength. (Begg and Kesling, 1977) For moving impacted teeth, special plus 0.016” archwire with straight length is preferred over spooled wire because they are more formable and less brittle. The Australian wire is bent with helices that serve as stops against the brackets of the adjacent teeth to maintain space for the erupting canine. An additional incisal helix increases the resiliency of the system and anchors the stainless steel ligature running to the canine attachment. The force vector for the canine can be altered by changing the transverse position of the incisal helix. The appliance is reactivated by twisting the steel ligature. This force also maintains space for the erupting tooth. The amount of force can be varied using different archwire designs. (Hauser *et al.*)

Monkey hook

Given by **Bowman *et al.* in 2002,** is a simple auxillary with an open loop on each end for the attachment of intraoral elastics or elastomeric chains, or for connecting to a bondable loop-button. Its S shaped design was inspired by the children’s game, “barrel of monkeys”, since more than one monkey hook can be linked together to form a chain. The hook can be closed with a plier to prevent disengagement. A combination of monkey hooks and bondable loop buttons allows the production of a variety of different directional forces to assist in the correction of impacted, rotated or displaced teeth. Apart from canine disimpaction monkey hooks can also be used for derotation and retraction.

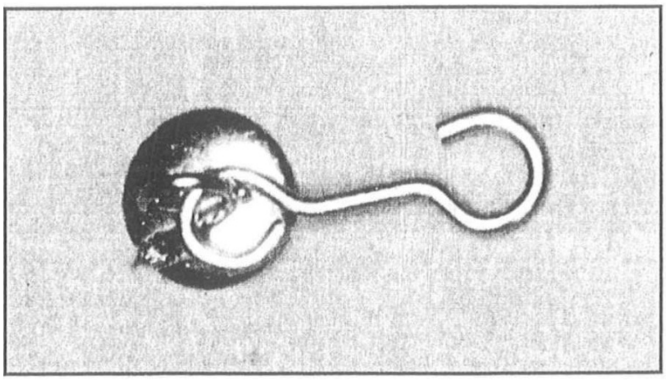


Fig. 9a. Monkey Hook is S-shaped wire linked to bondable “loop button”

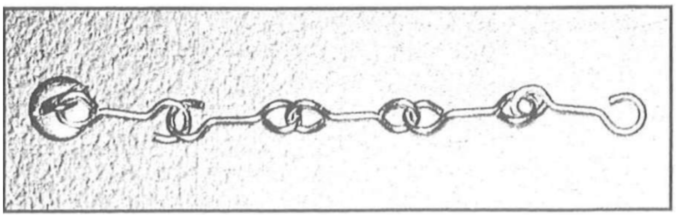


Fig. 9b. Monkey Hooks linked together into chain

Kilroy spring

Kilroy spring is a constant force module introduced by Bowman *et al.* (2003), which is slid onto a rectangular archwire over the site of an impacted tooth. The configuration of Kilroy reminded the designers of the popular “Kilroy was here” graffiti of 1940. In the passive state, the vertical loop of the Kilroy spring extends perpendicularly from the occlusal plane. To activate the spring, a stainless steel ligature wire is guided through the helix at the apex of the vertical loop, and the loop is directed towards the impacted tooth. The ligature is then tied to an attachment that has been direct-bonded to the surgically exposed tooth. A Kilroy spring can be tied to a loop button, monkey hook or a gold chain. Support for the activated Kilroy spring is derived from the continuous rectangular archwire and reciprocal forces from the incisal third of the adjacent teeth, which are contacted by the lateral extensions of the spring. The kilroy spring may nedd to be periodically retied to maintain a constant force as the teeth erupts. Kilroy II spring was designed to produce more vertical than lateral eruptive forces for the eruption of buccaly impacted teeth. Its multiple helices increases its flexibility, but also increases the likelihood of impingement on the adjacent soft tissue. Modified Kilroy spring was introduced by Sharma *et al.* (2015), which could be applied without removal of the deciduous canine, thus improving the patient esthetic appearance and helping to maintain the canine space. The base width of the vertical loop is determined by the width of the deciduous canine where the loop clears the deciduous canine in palatal direction.

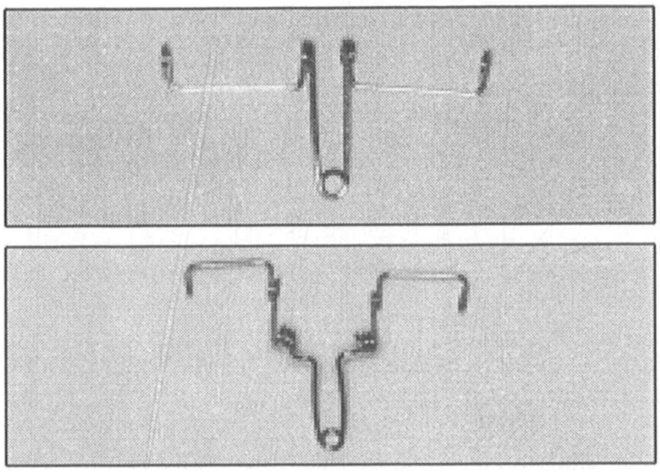


Fig. 10b. When passive, vertical loop of kilroy spring is perpendicular to plane of occlusion

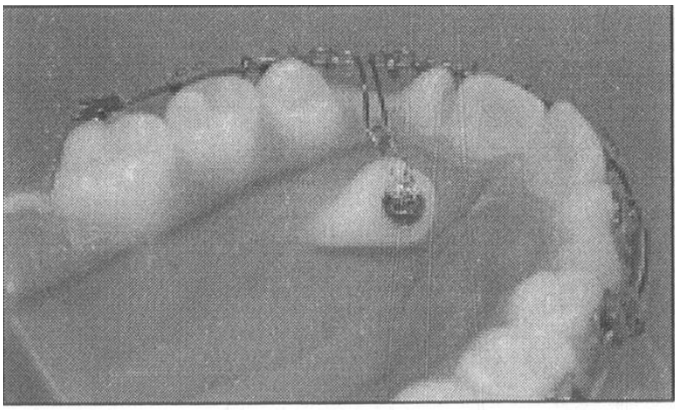


Fig. 10c. For activation, stainless steel ligature is passed through helix at end of vertical loop and ligated to bonded loop-button on impacted tooth

Table 1. A summary of orthodontic springs used to manage impacted canines

Harry Jacobay (1979)	Ballista spring
Criscini *et al* (1994)	Tunnel traction
Ali Darendeliler (1994)	Magnets
Becker *et al*. (1995)	Stainless steel archwire auxiliary
Lindauer and Isaacson (1995)	Cantilever spring TMA box loop
Samuels and Rudge (1997)	Two archwire technique
Loring L Ross (1999)	Nickel titanium closed-coil spring
Pramod K. Sinha (1999)	Mandibular anchorage
Varun Kalra (2000)	The K-9 spring
Christine Hauser C (2000)	Australian helical archwire
Jay Bowman (2002)	The monkey hook
Jay Bowman (2003)	Kilroy spring
Schubert M (2008)	Easy way coil system (EWC)
Arun and Shetty (2011)	Magnetic canine disimpactor
Vibhuti PKJ (2011)	Versatile auxillary orthodontic spring
Rizvi and Nayak (2015)	Modified disimpaction spring

Easy-Way-Coil (EWC) system

The EWC system introduced by Schubert (2008) consists of a Remanium closed-coil stainless steel spring, 0.010" ligature wire and a bondable lingual button. The spring has an outer diameter of .047" and an inner diameter of .030". Each 1mm of activation generates an average force of .158N or 16.1gms. To assemble the system, cut a 1" length of spring with a ligature cutter. At one end, carefully bend the last few coils of the spring at a 45° angle to make an eyelet about 1mm in length. Attach the eyelet to the lingual button with the .010" ligature wire. After twisting and trimming the ligature wire to a length of 1.5mm, firmly press the end against the stem of the button with a band adapter. It is important to ensure that the attachment can still be turned for subsequent activation. The spring should be reactivated at four week intervals to maintain a constant force. After the crown will has emerged enough to remove the lingual button and place a bracket on the tooth. Further alignment can be accomplished with a "piggyback" arch segment. The EWC system allows the constant application of force throughout the eruption of impacted teeth. It can be applied either unilaterally or bilaterally, with secure anchorage and no undesirable side effects.

Conclusion

The other appliances available include magnetic canine disimpactor (MCDA) (Arun and Shetty, 2011), modified disimpaction spring (Vibhuti, 2011), versatile auxillary orthodontic spring (VAOS) (Aziz Rizvi *et al*., 2015). Special attention is given to the article by Vanarsdall and Corn, (Vanarsdall and Corn, 1977) in which they have emphasized the importance of attached gingival that remains after the retraction of labially impacted tooth. When dealing with unerupted teeth surgeons must carefully plan his flap and bring attached fibrous mucosa in contact with the operated tooth. Generally palatally impacted tooth is surrounded by attached mucosa, and on contrary the vestibular impacted tooth, or the lower lingually impacted tooth may be drawn through the loose gingival mucosa, and the final result could be a good orthodontic alignment with poor periodontal mucosal attachment. This article highlights most of the common disimpaction springs which can be used for alignment of canines. Careful selection of surgical and orthodontic techniques is essential for the successful alignment of impacted canines.

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