# SELF-ACTIVATING PISTON-TUBE ORTHODONTIC MODULE FOR CONSTANT FORCE DELIVERY

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**Running title:** SELF-ACTIVATING PISTON-TUBE FOR CONSTANT FORCE DELIVERY

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***ABSTRACT***

The superelastic characteristics and generally constant force delivery of closed-coil nickel-titanium (NiTi) springs make them popular for orthodontic space closure. However, investigations conducted in vivo and in vitro show a quantifiable force decrease during clinical use. In order to sustain efficient NiTi activation throughout space closure, this clinical invention presents a self-activating piston–tube module. An open-coil compression spring serves as a compensating component, a closed-coil NiTi extension spring provides primary force delivery, and a sliding piston is housed in a metallic tube. The internal spring is compressed by piston action during space closure, preserving NiTi extension and minimizing force decay. This invention could increase anchoring control, decrease reactivation frequency, and improve biomechanical predictability. The design is a step toward orthodontic force devices that can regulate themselves.

**Keywords:** Force decay, Nickel-titanium springs, Orthodontic force, Piston-tube, Self-activating, orthodontic space closure.

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## Introduction

For effective and physiologically safe tooth movement, controlled orthodontic force delivery is essential. Light, sustained orthodontic pressures are usually ideal for maximizing tissue responsiveness and reducing side effects. According to studies, the ideal orthodontic forces for a variety of tooth movements may be between 50 and 100 g, while there may be some variance based on clinical circumstances.[1,2]

Because of their superelastic characteristics and capacity to exert a comparatively consistent force throughout wide activation ranges, closed-coil NiTi springs are frequently utilized. Clinical data, however, indicate that force deterioration happens during intraoral usage and that genuine consistent force administration is not accomplished.[3]

According to recent findings, NiTi coil springs may exhibit detectable in-vivo force deterioration (about 15% under certain circumstances), which could affect the uniformity of force delivery. Systems that can sustain continuous activation of orthodontic force delivery devices without requiring frequent chairside reactivation are therefore clinically necessary.[4]

A decaying spring force system can be transformed into a self-compensating force delivery mechanism with the help of the suggested piston–tube module. The primary concept is to maintain the effective extension length of the NiTi spring and compensate for the activation loss during space closure.

***Design Description of The Self-Activating Piston-Tube Orthodontic Module***

A closed-coil nickel-titanium (NiTi) extension spring acts as the main force generator, an open-coil compression spring acts as a compensatory element, a sliding piston acts as the force transmission unit, and an outer metallic tube acts as the anchorage housing. Additional parts include ventilation apertures to avoid fluid or pressure locking within the assembly and a retention ring or end stop to prevent piston disengagement. The piston is connected to the tooth that needs orthodontic movement, and the outer tube is fastened to a stable anchorage unit, like a temporary anchorage device or molar hook (Figures 1 and 2).

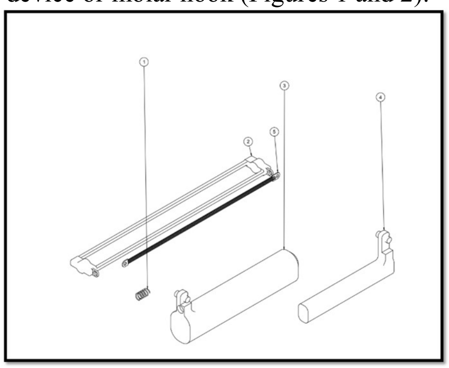

Fig 1- Exploded schematic representation of the piston-tube orthodontic force module

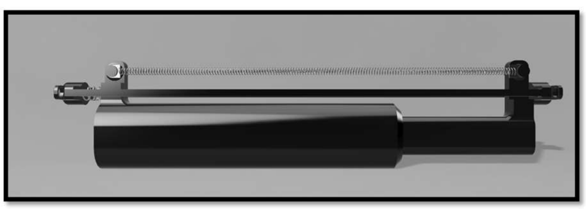

Fig 2- Assembled three-dimensional representation of the piston-tube orthodontic force module

***Biomechanical Mechanism of Constant Orthodontic Force Delivery***

Nickel-titanium (NiTi) coil springs gradually shorten as the extraction space shrinks during conventional space closure, which causes force degradation over time. The open-coil spring in the piston module is compressed as the piston advances into the tube as the tooth travels distally, enabling it to store mechanical energy. By preserving the closed-coil NiTi spring's effective activation length, this technique promotes more reliable force delivery during tooth movement. To maintain a net distal force on the tooth, the compensatory spring attached to the device works and acts against the anchorage unit rather than against tooth movement.

During activation, the closed-coil NiTi spring is expected to experience a force reduction of approximately 18–20%. The open-coil NiTi spring, which compresses while the closed-coil spring elongates, efficiently compensates for this force reduction and helps maintain more consistent force delivery within the system.

Because the suggested piston-tube module keeps the closed-coil NiTi spring effectively activated, it may help reduce force decay during space closing. This could assist in transmitting force more consistently throughout treatment and lessen the frequency of chairside reactivation. The technology can help preserve anchoring control during space closure and enhance biomechanical predictability by stabilizing the spring's mechanical activation length. Additionally, by reducing force application interruptions, consistent force delivery may enhance therapy effectiveness. The need for systems made to stabilize orthodontic force delivery is further supported by reports of force delivery variability across various NiTi coil springs in the literature (Figure 3).

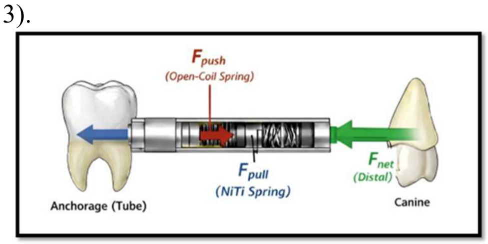


Fig 3- Schematic illustration of force vectors within the piston-tube orthodontic module during space closure

***Future Directions In Smart And Adaptive Orthodontic Systems***

Micro-force sensors could be incorporated into this device in the future to allow for real-time orthodontic force delivery monitoring. Using CAD-CAM technology for digital customization could enable the creation of patient-specific modules that are suited to each person's unique space and biomechanical requirements.

Clinicians may be able to alter force delivery without having to replace the complete device due to the development of modular spring cartridges with different force levels. To confirm the system's long-term performance, biological response, and therapeutic efficacy, more clinical trials will be required. Furthermore, data-driven therapy modifications and remote tracking might be made possible by integration with digital orthodontic monitoring platforms. Recent studies emphasize how crucial precise force management and monitoring are to maximizing the results of orthodontic therapy.

**Conclusion**

The self-activating piston-tube module is a new biomechanical method of applying force in orthodontics. The technology may increase treatment efficiency and predictability by sustaining efficient NiTi activation during space closure. To prove long-term clinical performance and safety, more biomechanical and clinical validation research is needed.

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**Figure Legends**

Fig 1- Exploded schematic representation of the piston-tube orthodontic force module

Fig 2- Assembled three-dimensional representation of the piston-tube orthodontic force module

Fig 3- Schematic illustration of force vectors within the piston-tube orthodontic module during space closure