Force characteristics of nickel-titanium open-coil springs

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Introduction: The objective of this study was to quantify the properties of commercially available nickel-titanium open-coil springs.

Methods: Eleven springs from 3 manufacturers were tested 5 times over a 12-week period. A universal testing machine was used to measure the force generated when open-coil springs were compressed to half of their original length and then gradually allowed to decompress.

Results: The average forces generated at the initial recording session for uniformly wound springs from GAC International (Bohemia, NY) and 3M Unitek (Monrovia, Calif) were 19.3% to 42.7% and 9.7% to 38.8% below the manufacturers’ labeled force levels, respectively. GAC’s 100, 150, and 200 g stop-wound coils demonstrated statistically and clinically significant stepwise force degradation over the 12-week experimental period \((P < 0.0001)\). GAC’s uniformly wound light (100 g) coils generated the lowest load-deflection ratios \((23.7 \, g/mm)\).

Conclusions: Open coils might need to be compressed by more than one-third of their original length to produce the labeled forces. Uniformly wound coils generally produce lower load-deflection ratios and maximum forces, which are generally more acceptable for tooth movement.

Read the full text online at: www.ajodo.org, pages 142.e1-142.e7.

EDITOR’S COMMENT

Coil springs have been a useful intraoral tool for space closure and opening for decades. The application supposedly became more reliable with the introduction of the nickel-titanium (NiTi) alloys, which offer steady force-deflection ratios, independent of compression. The objective of this study was to quantify the properties of commercially available NiTi open-coil springs used in everyday orthodontics through a simplified in-vitro test, which nonetheless provided useful information. The authors selected 11 different springs from 3 manufacturers and tested them 5 times over a 12-week period; they used a testing machine with the coils compressed to half of their original length. The average forces generated at the initial recording session for uniformly wound springs varied but were as high as 39% below the manufacturers’ labeled force level. The results generally suggested that the forces developed deviated from the manufacturers’ specifications, and clinicians might want to consider modifying the compression percentages of coil springs. Also, uniformly wound coils generally produced lower load-deflection ratios and maximum forces, which are usually considered more acceptable for tooth movement. Although these results derive from an in-vitro study, and thus the extrapolation of absolute values to clinical conditions might not be accurate, this article highlights the variability between reported and actual values, and emphasizes the necessity for strict quality-control measures and screening the properties of orthodontic materials.

Theodore Eliades
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Q & A

Eliades: Can your suggestion on modifying the compression range of coil springs be generalized to all products available?

Bourke: Not necessarily. So many variables affect the force characteristics of open-coil springs including the material composition (percentages of nickel, titanium, copper, and other elements) and spring design (eg, pitch, spring diameter, wire size). Different manufacturers’ open-coil springs could have varying properties. Therefore, I think that further investigation of other commercially available springs is required before generalizing the recommendations of this study.

Eliades: What would you expect to notice in the actual clinical application of materials in the oral environment where the multifactorial aging pattern (eg, masticatory forces, pH and temperature fluctuations, oral flora) might affect the expression of force by the coil springs?
**Bourke:** In a clinical setting, the forces expressed by the springs would be expected to be much more variable than in our study. We kept the springs in a simulated oral environment of physiologic saline solution maintained at 37°C throughout the study period. We made every attempt to keep conditions as close to in-vivo conditions as possible. However, the mouth is constantly undergoing temperature changes that would alter the phase of the NiTi and thus affect force delivery. Nattrass et al\(^1\) examined the effects of oral environmental factors including temperature and food on NiTi closed-coil springs. They showed that force delivery of the NiTi coil was unaffected by immersion in Coca Cola, water, or turmeric solution, but was affected by changes in temperature. Our study also did not assess the effect of perturbations from mastication and occlusion that might play a role in the aging of the material, especially after prolonged use.

**Eliades:** Have you considered examining retrieved coil springs to achieve the extrapolation of clinically applicable information as noted in the previous question? Removing the coil spring after 12 weeks, for example, and measuring the force expressed would bypass the in-vitro character of this type of research.

**Bourke:** Obviously, a limitation of our study was its in-vitro nature. Testing springs retrieved after intraoral use would be an excellent future direction of study. It could provide information on intraoral changes leading to alterations in the force characteristics and properties of the springs. Previous research has shown that NiTi wires exhibit changes in surface roughness after intraoral use.\(^2\) However, we are unaware of any studies that have examined the changes that occur specifically to open-coil springs after intraoral use. The obvious advantage of the in-vitro design was that all other factors could be controlled, so variability was limited (eg, it would be difficult to find consistent intraoral applications in many patients with the length of the coil spring segments kept the same).

**Eliades:** Were the study conditions representative of the use of the springs in a clinical setting when considering force degradation over time?

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**REFERENCES**