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Resistance to bending and buckling of WaveOne and Reciproc instruments

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Introduction: This study evaluated the cross section, resistance to bending and buckling of Reciproc and WaveOne instruments.
Methods: Reciproc R25 (VDW, Munich, Germany) and WaveOne Primary (Dentsply Maillefer, Ballaigues, Switzerland) instruments, all of them 25-mm long, with D0 diameter of 0.25 mm and taper of 0.08 mm/mm along the first 3 mm from the tip, had their cross section analysed and were subjected to bending and buckling resistance tests. The data from both tests were analysed using the Student *t* test.
Results: A statistically significant difference was observed between the maximum load to bend Reciproc 25 and WaveOne Primary instruments ($P < 0.05$). Higher values were necessary to bend WaveOne Primary instruments when compared with Reciproc R25. In contrast, there was no statistically significant difference between the maximum load to buckle Reciproc 25 and WaveOne Primary instruments ($P > 0.05$).
Conclusions: Both instruments exhibited similar behaviour in terms of buckling resistance. However, Reciproc R25 was more flexible, which is an important instrument property for the shaping of narrow and curved root canals.

Introduction

Factors that may influence the fracture of engine-driven nickel-titanium (NiTi) instruments rotating in a clockwise motion include the way that the instruments were manufactured (twisted or grinding), their alloy characteristics (presence of absence of thermal treatment), resistance to bending, design, diameter, taper, length of working section, rotary speed and mechanical interaction with the root canal walls, as well as the effect of tooth anatomy and the operator's qualification and knowledge[1-6]. In an attempt to reduce the number of instruments used for root canal preparation, simplify the technique, save time, reduce the risks of canal contamination and further reduce the risk of instrument fracture, Yared[7] proposed a technique that utilises only one NiTi instrument in a reciprocating motion. Based on these preliminary successful results, single-instrument shaping systems, such as Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland), have been launched on the market. In the reciprocating technique, the instrument is first moved in one direction and then in the opposite direction to disengage it. The rotation angle is greater counterclockwise than of the movement in the opposite direction, so that the instrument advances continuously to the working length[8]. Studies using these single-instrument shaping systems have shown that the reciprocating technique is very safe, and that the instruments are resistant to torsion and have a useful life, longer than the engine-driven NiTi instruments used under continuous rotation[8-14].

In these single-instrument shaping systems, the same instrument is used for both cervical flaring and apical preparation. Therefore, in addition to the resistance to fracture, two other mechanical properties are very important for instruments to be used in shaping of curved root canals: bending and buckling. Flexibility is the capacity of an instrument to bend while submitted to a load perpendicular to its axis. The instrument should be flexible enough to be taken beyond the curvature during preparation of curved canal without promoting iatrogenic deformation of the canal shape. Buckling is the capacity of an instrument to buckle like a bow while submitted to a load parallel to its axis. Instruments that have low resistance to buckling may develop elastic or plastic deformation that hinders their apical progression in the root canal. Therefore, the present study evaluated the bending and buckling resistance of Reciproc and WaveOne instruments.

Material and methods

A total of 44 instruments were used for the tests: 20 Reciproc R25 (VDW) and 20 WaveOne Primary instruments (Dentsply Maillefer) 25-mm long, with D0 diameter of 0.25 mm and taper of 0.08 over the last 3 mm from the tip. Ten instruments were used for each test and four instruments, two of each brand, were embedded in acrylic resin and prepared for cross-section analysis using a scanning electron microscope (JSM 5800, JEOL, Tokyo, Japan).

Resistance to bending

The instrument resistance to bending was evaluated using a cantilever bending assay, as described by Serene et al[15] and modified by Lopes et al[16]. In short, a universal testing machine (Emic DL 10.000, São José dos Pinhais, Paraná, PR, Brazil) was used. The load was applied by a flexible stainless steel wire measuring 30 cm in length and 0.34 mm in diameter, with one of the extremities gripped at the testing machine head and the other end fastened 3 mm away from the instrument tip. The bending test was performed until the end of each specimen had been submitted to an elastic displacement of 45 degrees. Crosshead speed was 15 mm/minute, and the load cell was 20 N.

Resistance to buckling

The test was conducted according to the method described by Lopes et al[17]. An increasing load was applied in the axial direction of each instrument using a universal testing machine (Emic DL 10.000), and the maximum load until buckling (lateral elastic displacement) was recorded. A 20-N cell load was used. The upper part of the instrument was gripped at the crosshead of the universal testing machine, and the tip of the instrument touched the bottom of a small cavity prepared in an aluminium plate. The cavity was 1 mm in diameter and 0.5 mm deep. The load was applied axially from the crosshead to the tip, with a speed of 1 mm/min until a 1-mm compressive displacement along the instrument axis occurred. During the buckling test, it was possible to obtain for each instrument a diagram of load (N) × deformation (mm). The maximum load needed to induce the elastic displacement of the instrument up to 1 mm was regarded as the buckling resistance of the instrument.

Statistical analysis

The data from both tests were analysed using the Student *t* test, and the level of significance was set at 5% ($P < 0.05$).

Results

Cross-section analysis

The Reciproc R25 instruments presented an S-shaped cross section and the spirals in counterclockwise direction. The WaveOne Primary instruments also had spirals in clockwise direction, but the cross-sectional design was concave and triangular near the tip and changed along the shaft (Figs 1 and 2).

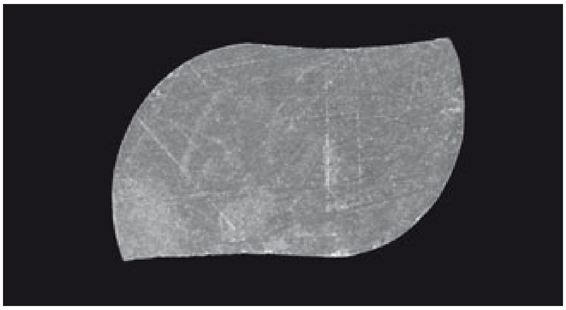

Fig 1 Cross sectional shape at D9 of the Reciproc instrument.

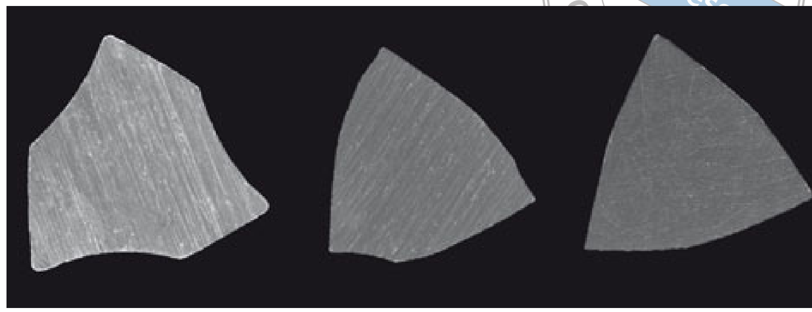

Fig 2 Cross sectional shape of WaveOne instruments (different cross sections along the working part from the tip (left) to the shaft (right).

Resistance to bending

Mean and standard deviation values of resistance to bending are shown in Table 1. There was a statistically significant difference between the maximum load to bend Reciproc 25 and WaveOne Primary instruments ($P < 0.05$). Extremely high values were necessary to bend WaveOne Primary when compared with Reciproc R25.

Resistance to buckling

Mean and standard deviation values of resistance to buckling are also shown in Table 1. The maximum loads to buckle Reciproc 25 and WaveOne Primary instruments were not statistically different ($P > 0.05$).

Discussion

Resistance to buckling may play an important role in the advancement of the instrument apically during the cleaning and shaping of narrow and curved root canals[17,18]. In the new single-file shaping systems using reciprocating motion, the same instrument is used for both cervical flaring and apical shaping. For cervical flaring, it is important that the instrument working in the straight section of a narrow canal should be resistant to a vertically applied load, i.e., it should exhibit resistance to buckling. In this study, Reciproc and WaveOne instruments did not significantly differ in buckling resistance.

The type of movement applied to the instrument may also contribute to the safe and efficient advance of Reciproc and WaveOne instruments. The alternation of rotation angles, that is, moving the instrument in a counterclockwise direction first and then in a clockwise direction to disengage it, produces a much lower rotation angle than the one to which the instrument is submitted when in continuous rotation. It also reduces the chances of elastic and plastic deformation and of possible separation due to rotary torsion or rotary bending[8,12,17,19].

Table 1 Mean and standard deviation values of the maximum load (g) of resistance to buckling and bending of WaveOne Primary and Reciproc R25 instruments.

Instruments	Buckling (g)	Bending (g)
WaveOne Primary	607.6 (31.03)	544.8 (19.98)
Reciproc R25	581.6 (17.44)	274.9 (19.02)

Several studies, both with engine-driven NiTi instruments under continuous motion and with instruments under reciprocating movement, have demonstrated that the more flexible the instruments are, the greater is the possibility of keeping canal preparation centralised[20-22]. In this study, Reciproc R25 was more flexible than WaveOne Primary. This result may be directly associated with the different geometric design of the cross sections of the instruments under test. Reciproc R25 instruments had an S-shaped cross section along all of its length, whereas the WaveOne Primary instruments had a concave triangular cross section at the apex, which changed along its shaft. This change in the shape of the cross section, from concave to convex, is probably the main explanation of the greater rigidity of the WaveOne instruments when compared with the Reciproc instruments. This result corroborates findings by other authors, who confirmed that the area of the cross section was inversely proportional to the flexibility of root canal instruments[2,23-25]. In addition to keeping the preparation of curved root canals centralised, instrument flexibility may significantly reduce the risk of separation due to rotary bending[12,20,26]. Resistance to bending may also be affected by thermal treatment, but both instruments tested in this study are manufactured using the same type of wire (M-wire) and, therefore, it is not likely that this factor had any type of effect in this study[8,12,19,27].

The results of this study demonstrated that both WaveOne Primary and Reciproc R25 instruments were resistant to buckling during cervical flaring. However, Reciproc R25 had lower resistance to bending, which is important when shaping narrow and curved root canals, as it may result in more centralised preparations and reduce the risk of separation due to rotary bending during clinical use.

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