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The effect of spreader size on fracture resistance of maxillary incisor roots

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Abstract

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Aim To assess the effect of spreader size used during cold lateral compaction of gutta-percha on fracture resistance of roots in maxillary incisor teeth.

Methodology The crowns of 50 human maxillary incisor teeth having no carious lesions, no fracture or crazing were resected 2 mm coronal to the cemento-enamel junction. The root canals of the teeth were prepared as follows: Group 1: No canal preparation. Group 2: Preparation using the stepback technique to a size 40 master apical file. Group 3: Canal preparation to size 40 and filling with laterally compacted gutta-percha; the first spreader used was equal to size 40. Group 4: Same as group 3 except the first spreader was equal to size 35. Group 5: Same as group 3 except the first spreader was equal to size 25. For each root, a simulated periodontal ligament was prepared. The roots were than mounted in polyester resin and fractured vertically on a universal testing machine (Shimadzu, Tokyo, Japan). The fracture values of teeth were analysed using Kruskal–Wallis and Mann–Whitney *U*-tests ($P = 0.05$).

Results: The uninstrumented group had the highest fracture resistance; instrumented, but unfilled roots, demonstrated the lowest resistance values ($P = 0.009$). There were no differences between the uninstrumented group and group 5 in which a size 25 spreader was used during filling. Use of spreaders larger than size 25 caused a significant reduction in fracture resistance of roots ($P < 0.05$).

Conclusion: Spreader size used during lateral compaction of gutta-percha can affect the fracture resistance of roots in extracted teeth.

Keywords: fracture resistance, lateral compaction, spreader size, vertical root fracture.

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Introduction

Vertical root fracture is a longitudinal fracture of the root, initiating from the crown or root apex, or along the root between these points (Pitts & Natkin 1983). It is a familiar complication during and after root canal treatment (Meister *et al.* 1980, Harvey *et al.* 1981, Holcomb *et al.* 1987, Schmidt *et al.* 2000) presenting a significant clinical problem, which is difficult to diagnose and treat (Pitts & Natkin 1983). It is well known that most fractured teeth, when no history of trauma is reported, have been root filled (Meister *et al.* 1980, Tamse 1988). Such catastrophic failure is one of the major causes of tooth extraction following root canal treatment despite promising therapies using new materials (Schwartz *et al.* 1999, Cohen *et al.* 2003).

It has been demonstrated that vertical root fracture can occur following canal preparation alone (Onnink *et al.* 1994). It has been speculated that some vertical root fractures begin during canal instrumentation and filling, and progress to more extensive fractures with time and occlusal stress (Walton *et al.* 1984, Onnink *et al.* 1994).

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Cold lateral compaction of gutta-percha is taught and practised in every part of the world (Qualtrough *et al.* 1999, Jenkins *et al.* 2001, Hommez *et al.* 2003) and remains the standard against which other methods of canal filling are compared (Dummer 1997, Whitworth 2005). In this technique, it is recommended that the initial spreader selected for compaction should be tried-in the instrumented canal prior to gutta-percha insertion. It has been advised by some authorities (Ingle & West 1994) that choice of a spreader should be equal to the master apical instrument size or one size larger and touching the canal wall within 1.0 to 2.0 mm before the end-point of preparation. However, there is little information on how lateral compaction is best practised in most textbooks or technique guides, postulating the best method of selecting and manipulating the spreader (VanGheluwe & Wilcox 1996, Bal *et al.* 2001).

Trope & Ray (1992) found that filling of the root canal with a single gutta-percha cone technique and a glass ionomer cement based root canal sealer abated fracture of roots significantly more compared with a lateral condensation technique and zinc oxide eugenol sealer. This result may be explained by the single-cone obturation procedure in which wedging effect of spreader and compaction forces are not created. Indeed, Saw & Messer (1995) suggested that the stress originating from the filling procedure may be generated by a wedging effect of the spreader. Blum *et al.* (1998) demonstrated that greater wedging effect occurred during lateral compaction, compared to warm vertical compaction, thermomechanical compaction and thermafil condensation.

The wedging effect appears when the filling material is pushed apically between the canal wall and spreader (Schilder 1967, Buchanan 1991). During vertical compaction, when the spreader size is small or the coronal part of the master gutta-percha cone is narrower, the resulting wedging effect decreases. During warm vertical compaction procedure, the smaller the plugger size, the lower the wedging effect (Blum *et al.* 1998). However, according to previous knowledge, the choice of an initial spreader, which matches the master apical file size or one size larger, has been recommended prior to obturation (Ingle & West 1994).

The possibility of vertical root fracture is increased when a stiff spreader with greater taper is used (Dang & Walton 1989). A number of factors have been investigated previously including, the effect of the type of spreader on vertical root fracture (Dang & Walton 1989, Murgel & Walton 1990), strain occurring during lateral condensation with strain at fracture (Holcomb *et al.* 1987, Lertchirakarn *et al.* 1999), relationships of fracture loads and root canals, spreader penetration depths and rates of spreader load increase (Harvey *et al.* 1981, Gimlin *et al.* 1986, Lindauer *et al.* 1989, Sakkal *et al.* 1991, Wilcox *et al.* 1997, Lertchirakarn *et al.* 1999, Hong *et al.* 2003). However, there are few studies on the relationship between spreader size and vertical root fracture. Therefore, the aim of this study was to evaluate the post-canal filling effect of spreader size on fracture resistance of maxillary incisor roots.

Materials and methods

Fifty recently extracted human maxillary incisors were selected and stored for 2 months in 0.1% thymol solution at 4 °C. The root surfaces were thoroughly cleaned of soft tissue and calculus using hand scaling instruments. All root surfaces were examined at ×20 magnification in a stereomicroscope for any root fracture, root resorption or crack. Periapical radiographs were taken to determine any teeth with previous pulpal obliteration or aberrant canal morphology. Teeth with cracks, root caries, open apices, pulpal obliteration or aberrant canal morphology were excluded. Instrumentation and canal filling were conducted by one operator.

Each tooth was hand held in gauze saturated with water during all instrumentation steps. The crown of each tooth was resected using a diamond bur (Number 847.018, North Bel, Milan, Italy) under water coolant 2 mm coronal to cemento-enamel junction measured on the buccal and lingual aspects. The working length was determined to be 1 mm short of the length that a size 10 file was observed to exit the apical foramen (Regan & Gutmann 2004). Roots in which a size 25 instrument fitted snugly at the working length were selected. Fifty roots were randomly divided into five groups each of 10 teeth as follows:

Group 1: No canal preparation

The roots ($n = 10$) remained uninstrumented and unrestored.

Group 2: Canal preparation only

The canals ($n = 10$) were prepared using a stepback technique as follows:

The apical foramen was kept patent to a size 15 file. The preparation commenced with size 25 H-type files

(Dentsply Maillefer, Ballaigues, Switzerland) that bound in the canal at the working length in all prepared roots. Instrumentation continued through three sequentially larger H-type files, and thus, the master apical file was size 40 in all roots.

Each file in the preparation was used in a circumferential filing action until it was loose at the working length. Two millilitres of 2.5% sodium hypochlorite was used to irrigate the canal after each instrument. The coronal third of the canals were flared with Gates Glidden burs sizes included 3 and 4. The stepback phase of canal preparation began with the size 45 H-files and five larger H-files up to size 70. A master apical file was placed gently towards the apical region to check whether the apical stop had been created.

Recapitulation was performed between each file. The final irrigation was carried out with 3 mL of 2.5% sodium hypochlorite. The roots were maintained at 4 °C with 100% humidity after root canal shaping.

Root canals in group 2 received no root filling.

Group 3: Lateral compaction; Spreader = MAF = Size 40

Canal preparation and filling with laterally compacted gutta-percha were performed on 10 roots; the first finger spreader used was size 40, .02 taper.

The roots were instrumented as in group 2. Lateral compaction was performed as follows:

The size 40 gutta-percha (master apical) cone (DiaDent Group International Inc., Chongju City, Korea) was tried-in at working length. Prior to filling, size 40 finger spreaders (Thomas Endo, Bourges Cedex, France) were set to length with a silicone stop, and placed in the canal space without binding to within 1 mm of the working length. Next, the filling was initiated by placing Diaket sealer (3 M, ESPE, Seefeld, Germany) on the canal wall using the master apical cone (size 40). When the master apical cone was seated to length, the size 40 spreader was inserted into the canal with apical pressure, 1 mm shorter than the working length. This initial spreader was left in place for 10 s to allow the primary gutta-percha cone time to reconform to this pressure. The spreader was then removed with a reciprocating motion and was immediately replaced by the first size 35 auxiliary point inserted to the full depth of the space left by the spreader. Following the compaction of the master cone using the initial spreader, only size 25 spreaders were used subsequently. Size 20 auxiliary cones were added until the size 25 spreader could penetrate no more than 2 mm. All gutta-percha cones used in this study were from the same lot or batch (DiaDent Group International Inc., Chongju City, Korea) and stored under identical conditions to eliminate variation in their physical properties. When the filling phase was completed, excessive gutta-percha was removed by a hot instrument. The roots were left unrestored.

Group 4: Lateral compaction; Spreader = Size 35

Canal preparation and filling with laterally compacted gutta-percha were performed on 10 canals; the first spreader used was equal to size 35.

The canals were instrumented and filled in the same manner as group 3, except the first spreader was equal to size 35. When the master apical cone was seated to length, a size 35 spreader was inserted into the canal 1 mm shorter than the working length, and a size 30 accessory cone was placed into the space created.

Group 5: Lateral compaction; Spreader = Size 25

Canal preparation and filling with laterally compacted gutta-percha were performed on 10 roots; the first spreader was equal to size 25. Canal preparation permitted the initial spreader to be inserted along the side of the master cone to 0.5 mm short of the working length. During the filling procedure, a size 25 spreader was not extended beyond the apical foramen.

The roots were instrumented and filled as group 3, except the first spreader was equal to size 25, and a size 20 accessory cone was placed into the space created.

All roots were wrapped in a single layer of aluminum foil to 2 mm below the cemento-enamel junction. They were embedded in separate standard ($15 \times 15 \times 15$ mm) plastic holders to the level of the cemento-enamel junction with polyester resin to create artificial sockets. After the setting of the resin the aluminum foil was removed, the light body silicone (ISO 4823, Type 3, low consistency, Speedex light body, Coltene/Whaledent) was mixed according to the manufacturers' instructions and was injected into the socket; the root was replaced carefully 2 mm below the cemento-enamel junction (Wilcox *et al.* 1997). This procedure provided a simulated periodontal ligament and also stability through the 2 mm collar under the cemento-enamel junction (Fig. 1).

A circle cross-sectioned crosshead tip having an area of 4 mm^2 was mounted on universal testing

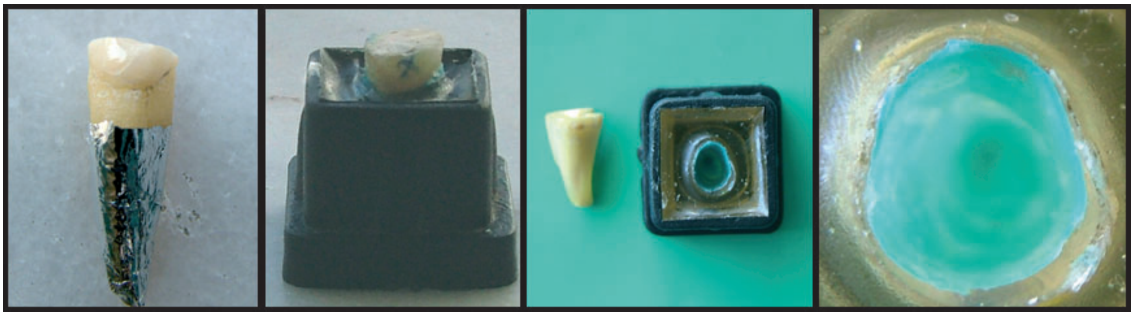

Figure 1 Images demonstrating the production of the artificial sockets.

Figure 2 Crosshead tip was used to apply vertical force to the root.

machine (Shimadzu, Tokyo, Japan) to apply vertical force to the root (Fig. 2). The root was centered under the crosshead tip and its coronal cut surface was parallel to the lower plate. The circle tip was driven downward exactly in the long axis of the root on the centre of the root surface with slowly increasing force at the rate of 0.5 mm mins^{-1} until the root fractured. The fracture was evidenced by an audible 'crack' and/or a sudden release of the tip load as seen on the graph. The force at fracture of each root was recorded.

Statistical analysis was performed using StatView 4.57 software (Abacus Concepts Inc., NC, USA). The Kruskal–Wallis test was used to determine variances among all groups followed by, pair wise comparisons using Mann–Whitney *U*-test. All statistical analysis was performed at the 95% level of confidence.

Results

The mean force at fracture for each experimental group is presented in the Table 1. The smallest fracture load was 62.1 kg (a sample in group 4 spreader size 35), while the highest fracture load was 163.7 kg (in the 'no canal preparation' group). The Kruskal–Wallis test demonstrated significant differences among the groups ($P = 0.0119$). The Mann–Whitney *U*-test revealed no differences between the 'not instrumented' and 'size 25 spreader' roots ($P = 0.790$). Forces that resulted in fracture of the 'not instrumented roots' were significantly greater than those of the roots filled using size 35 ($P = 0.0231$) and size 40 spreader ($P = 0.0084$) and those of the only instrumented group ($P = 0.0090$). No significant differences were found between the instrumented roots and those filled using size 40 spreaders ($P = 0.8836$).

Discussion

During lateral compaction, it has been accepted for many years that the initial spreader should reach to within 1 to 2 mm of the working length. The importance of spreader penetration depth was reported by Allison *et al.* (1979). However, it has been demonstrated that localized stress can be created at the end of the canal by the introduction of spreader that can remain throughout lateral compaction (Harvey *et al.* 1981,

Table 1 The mean force at fracture for each experimental group

Groups	Mean force (kgf) ± SD
Group 1	153.4 ± 7.2
Group 2	97.8 ± 12.9
Group 3	99.6 ± 20.7
Group 4	104.3 ± 30.8
Group 5	128.0 ± 22.9

Gimlin *et al.* 1986). Saw & Messer (1995) reported that a higher value of apical strain than coronal strain was generated during lateral compaction, probably because of the reduced thickness of dentine in the apical portion of the root and the greater wedging effect of the spreader tip in the narrower part of the canal (Blum *et al.* 1998). Vertical root fractures can occur in mandibular incisors with single canals even at spreader loads as small as 1.5 kg when the size of spreader is equal to that of the master apical file (Holcomb *et al.* 1987). Initial spreader size, which should reach 1 to 2 mm shorter than the working length, must be smaller than the master apical file to produce a good seal and avoid a wedging effect. A safe spreader size should be determined prior to each root filling.

Spreader design has been considered to be related to vertical root fractures in previous studies (Lindauer *et al.* 1989, Murgel & Walton 1990, Lertchirakarn *et al.* 1999). Walton (1996) suggested that the more flexible and less tapered finger spreaders are safer than stiff, conventional hand spreaders. It was demonstrated that using spreaders of a more tapered design caused 5% more incomplete root fractures (Dang & Walton 1989). However, no studies on the effect of spreader size on root fractures have been reported. The post-obturation effect of spreader size on vertical root fracture was examined in this study. All instrumentation and obturation procedures were also performed by one endodontist to simulate clinical practice.

The effect of spreader size on vertical root fracture was examined in this study. Vertical root fracture was produced by using a 4 mm^2 tip to apply vertical force to the root. Since the total surface of occlusal contacts in the static occlusion equal to 4 to 6 mm^2 (Hoffmann & Eismann 1991), this procedure reflected vertical root fracture contributed by occlusal forces. In lateral compaction, average condensation loads used by endodontists ranged from 1–3 kg (Harvey *et al.* 1981, Onnink *et al.* 1994) with maxillary incisors requiring the greatest spreader load to fracture teeth compared to different tooth groups (Pitts *et al.* 1983, Lertchirakarn *et al.* 1999). Using finger spreaders manually makes it difficult to achieve the load required to fracture roots. However, incomplete root fractures can be created during root canal treatment (Walton *et al.* 1984, Onnink *et al.* 1994).

The mean force at fracture for roots filled using size 25 spreaders was in the same range as uninstrumented canals but significantly higher than those of these roots those were only instrumented roots or filled using size 40 and size 35 spreaders. This result suggests that using a size 25 spreader initially to working length during lateral compaction did not jeopardize the strength of filled roots. On the other hand, using a size 40 spreader (equal to the master apical file size) decreased the fracture resistance of filled roots. Lateral compaction may result in incomplete root fractures. These incomplete fractures may become high stress concentration areas, when force is applied during the restorative procedure or from occlusal stresses during mastication (Onnink *et al.* 1994, Wilcox *et al.* 1997, Lertchirakarn *et al.* 1999, Hong *et al.* 2003). Spreaders that are larger than size 25 may increase the number of incomplete fractures, although further studies are necessary to confirm the potential phenomenon.

Dulaimi & Wali Al-Hashimi (2005) compared the effect of four different preparation techniques on spreader penetration depth and load required during lateral compaction. Their study showed that the stepback technique with Gates-Glidden drills resulted in the smallest distance between the initial spreader (same size as the master apical file 40) and the working length. However, the greatest mean value of spreader load was associated with the stepback technique. It is well known that the initial spreader should reach to 1–2 mm short of the working length to provide a good apical seal (Allison *et al.* 1979). The size of the initial spreader may be important to prevent extra loading. The present study revealed that spreader size equal to the master apical file decreased the fracture resistance of maxillary incisor roots. However, a size 25 spreader, which reached to within 1–2 mm of the working length, did not influence the fracture resistance of maxillary roots.

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