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A survey of interfacial forces used during filing of root canals

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Abstract – The pattern of dentine removal during endodontic instrumentation is influenced by many factors including the interfacial forces applied by the operator. The aim of this study was to investigate the influence of operators and different sizes and types of instruments on the magnitude of these interfacial forces. Single-rooted teeth were mounted on a cantilevered aluminium beam to which two pairs of single element strain gauges were joined in a half-bridge configuration and mounted at right angles to each other. The strain gauges were connected to an analogue-to-digital converter fitted in a micro-computer via conditioning amplifiers. This enabled strains to be recorded over a period of time. Twenty operators instrumented root canals using a series of hand instruments for 1 min each. The mean interfacial forces used by operators demonstrated a wide variation ranging from 9.06 g to 149.42 g (range of forces from 0–331 g) but there was a consistency in the relative magnitude for each operator. The 20 operators could be divided into 13 groups which were significantly different (α= 0.05) from each other. There were significant differences (α=0.05) between the forces used for each of the K-Flex files (15, 25, 35, 45, and 70), the force increasing with the file size. There was also a significant difference (α=0.05) in the forces used between the Flexofile (#25) and the #25 K-Flex and Hedström files. However, there was no significant difference between the K-Flex and Hedström files.

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The aim of filing root canals is to remove dentine in a controlled manner so as to produce a preconceived taper. Achieving this depends upon the cutting properties of the instrument, the physical properties of the dentine and the nature of the interaction between the two. The properties of the instrument dictate its mode of use which may involve a push-pull motion, a rotational motion or a combination of both. Conventional ISO files are generally designed to remove dentine optimally in the push-pull motion. Other variables which affect the efficiency of this action include the flexibility or rigidity of the instrument, the sharpness of the cutting edges, the presence or absence of irrigant (1) and the magnitude of interfacial forces used (2). The significance of this last factor has not been thoroughly investigated.

The great majority of endodontic instrumentation studies make no reference to the interfacial forces applied to the root canal walls (3–6). A small number of studies have evaluated the cutting efficiency of various instruments and have controlled or considered controlling the interfacial force. The selected interfacial force has either been chosen arbitrarily (7) or been based on pilot studies (8, 9). A recent study (2) investigated stroke rate and loading using hand, sonic and ultrasonic instruments.

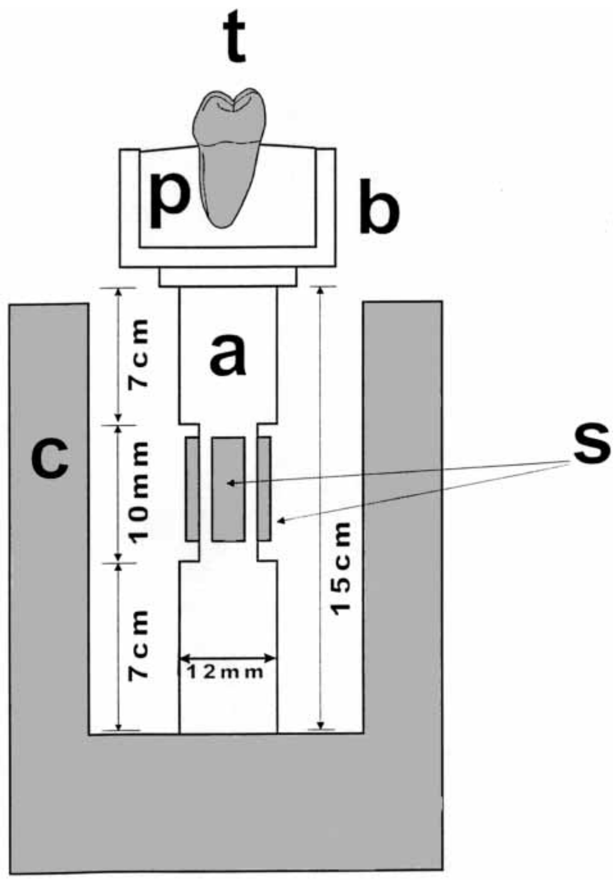
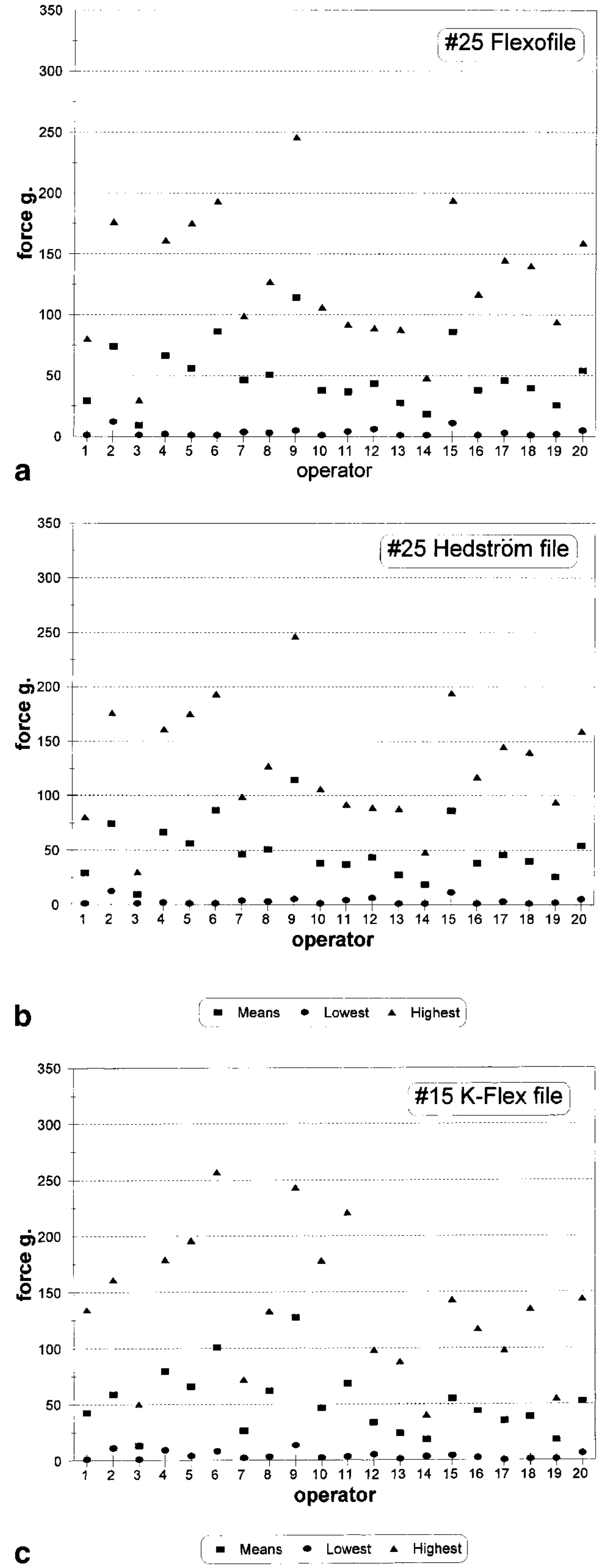


Fig. 1. Schematic diagram showing longitudinal section of the force measuring unit. t=tooth sample; p=plaster; b=brass well; a=aluminium beam; s=strain gauges; c=casing.



The aim of the present study was to investigate the magnitude of the interfacial forces applied to root canal walls by 20 operators during hand instrumentation with different types and sizes of files.

Material and methods

Twenty extracted human permanent teeth with relatively straight and large root canals were prepared in a standardised way as follows. Caries and defective restorations were removed and the length of the teeth was standardised to 17 mm from the root apex by grinding the occlusal surface.

The root canals were then prepared by filing until a #70 K-Flex file (Kerr Sybron, Bretton, Peterborough, UK) could be placed passively to the full length without binding. All of the samples were stored in distilled water prior to instrumentation as recommended by Waters (10). In order to measure interfacial forces applied to the root canal walls during instrumentation, the roots were mounted in quick-setting plaster of paris contained within machined brass wells. A specially designed force measuring unit was constructed. It consisted of a cantilevered aluminium rod, a sample

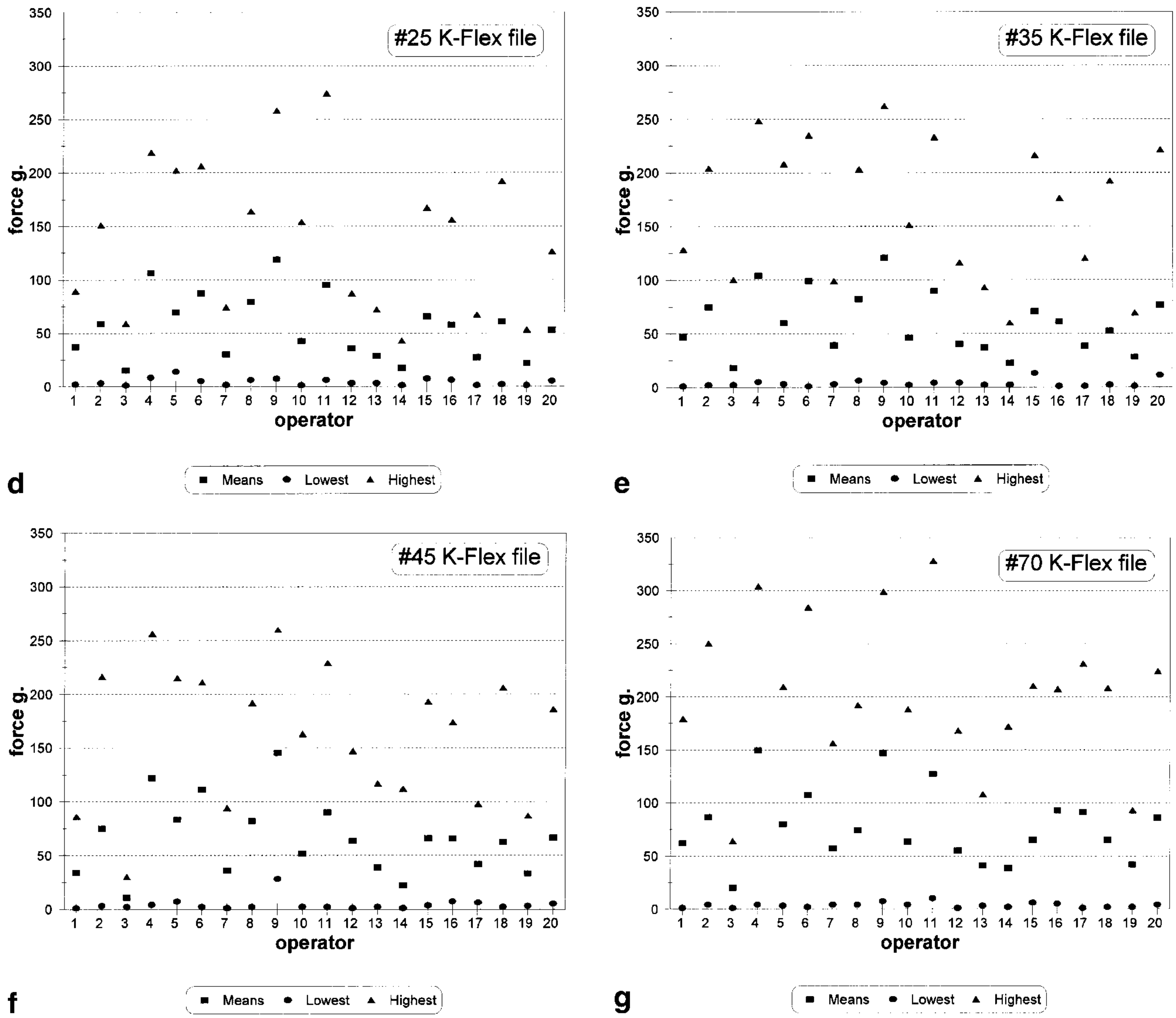


Fig. 2. a. Mean and range of forces used by operators with #25 Flexofile. b. Mean and range of forces used by operators with #25 Hedström file. c. Mean and range of forces used by operators with #15 K-Flex file. d. Mean and range of forces used by operators with #25 K-Flex file. e. Mean and range of forces used by operators with #35 K-Flex file. f. Mean and range of forces used by operators with #45 K-Flex file. g. Mean and range of forces used by operators with #70 K-Flex file.

housing unit and a casing. The rod was machined in the middle to receive two pairs of single strain gauges (type TLA 1-11, TechniMeasure, Worcester, UK) that were bonded axially in two pairs at right angles to each other and connected in bridge circuits to give an output proportional to the sideways instrumentation force in any direction (Fig. 1). The strain gauges were connected to two type 031 Sangamo-Schlumberger (Sangamo Transducers, Bognor Regis, UK) conditioning amplifiers with light emitting diode (LED) digital displays whose output was in turn connected to a micro-computer. Special software was prepared for this experiment which allowed the duration (60 s) and frequency of sampling time (100 Hz) to be set as required. Calibration of the strain gauges was carried out by applying a series of known weights. The calibration was repeated after every second operator to ensure accuracy of the results throughout the study.

Twenty experienced operators (post-graduate students or staff members in the Department of Conservative Dentistry, Eastman Dental Institute) were asked to participate in this study. Each operator was requested to instrument one of the standardised root canals with a series of seven hand files (#15 K-Flex file, #25 K-Flex file, #35 K-Flex file, #45 K-Flex file, #70 K-Flex file, (Kerr Sybron), #25 Flexofile, (Dentsply Maillefer, Ballaigues, Switzerland), and the #25 Hedström (Kerr Sybron). Each instrument was used in a circumferential filing motion for 60 s. Once during the instrumentation period for each file and be-

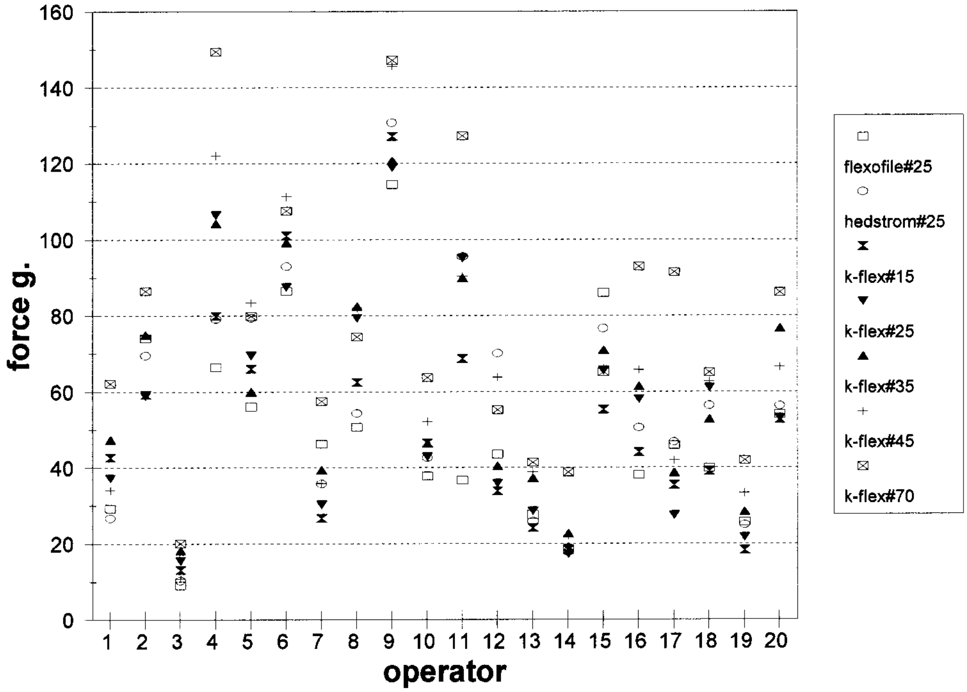


Fig. 3. Mean interfacial forces for seven hand files used by operators.

fore each new file was used the canals were irrigated with 2.5% sodium hypochlorite delivered by an endodontic syringe through a 27-gauge needle (Monoject Endodontic Locking syringe, Sherwood Medical, St. Louis, MO, USA).

One hundred and forty data sets were produced from the 20 operators using the seven different files. Each data set consisted of two sets of load data, representing the loads in the X and Y directions. Each minute of filing resulted in 270 recordings for loads exerted in the X direction and 270 recordings for loads exerted in the Y direction. Using the PC-28 software, the information was recorded, stored, and subsequently entered into a series of spreadsheets (Borland Quattro Pro, Borland International, Scotts Valley, CA, USA).

The resultant force applied was calculated by taking the square root of the sum of the squares of the individual vectorial components (X+Y) to give a total of 270 values. The average of these 270 values gave an indication of the mean force used by each operator (n=20) with each file (n=7). The total number of observations in the data set was 37 800 (i.e., 270×20×7 observations). The data were statistically analysed first by analysis of variance (ANOVA) and then a series of Bonferroni corrected t-tests (11).

Table 1. Bonferroni groupings for the 20 operators

Bonferroni grouping	Operator	Mean forces
A	9	123.65
B	4	99.63
C	6	89.57
	11	87.68
D	8	73.27
E	15	69.43
	16	67.33
F	5	61.94
	2	60.24
G	20	55.93
	18	52.74
H	10	47.98
I	7	43.88
	1	42.41
	12	41.16
J	17	37.73
K	13	30.56
	14	30.10
L	19	26.49
M	3	18.09

Note: α=0.05.

Table 2. Bonferroni groupings for file types and sizes

Bonferroni grouping	Mean force in grams	File type and size
A	77.3	#70 K-Flex
B	65.42	#45 K-Flex
C	60.479	#35 K-Flex
D	57.141	#25 Hedström
	56.932	#25 K-Flex
E	50.558	#15 K-Flex
	50.146	#25 Flexofile

Note: α=0.05.

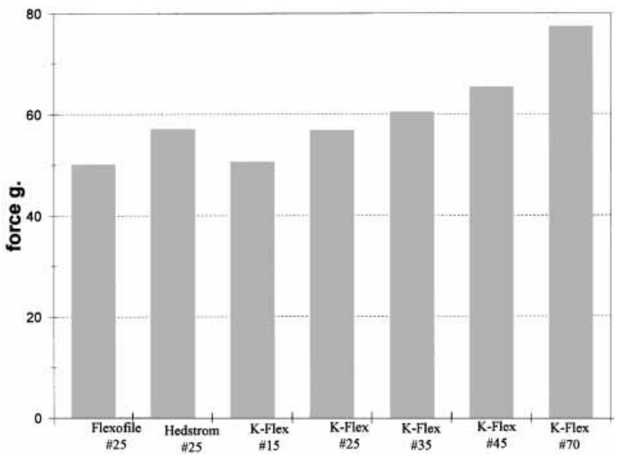


Fig. 4. Mean interfacial forces for seven hand files.

Results

The data showed that a wide range of interfacial forces was used by the operators for each of the files (Fig. 2a–2g). The mean forces used by the 20 operators using the hand files varied from 9.06 g to 149.42 g.

The pattern of interfacial forces for file type, size and operators is seen in Fig. 3. This, together with Fig. 2a–g, shows that each operator used a range of different forces for each file. Although some operators used vastly different forces from other operators the mean range of forces each operator used was characteristic for that operator.

Statistically, the operators could be divided into 13 separate groups that were significantly different from each other (α=0.05) (Table 1). Forces applied by operators in a given group were not significantly different from those applied by other operators in that group.

Despite the large general variations amongst operators, the pattern of forces used for each file by each operator was relatively consistent (Fig. 3). Although there were some individual exceptions (Fig. 3), the mean interfacial forces for each file showed a gradual increase with file size (Fig. 4). There were significant differences between each of the K-Flex files (α=0.05) as judged by the Bonferroni groupings (Table 2). The comparison between file types showed no significant difference (α=0.05) between the #25 K-Flex and Hedström files but a significant difference between them and the #25 Flexofile (Fig. 4 and Table 2). The Flexofiles generated much smaller interfacial forces equivalent to a size 15 K-Flex file (Table 2).

Discussion

Interfacial force is a function of several interactive factors including the resilience of the file and that of the tooth in its mounting, the tactile sense perceived, and ultimately the force applied by the operator.

The method used has been evaluated previously in another study by our group and found to be a useful and simple way to study interfacial forces. In this study, only straight canals already prepared to accept a #70 file were used to eliminate the variables inherent in root canal morphology. The use of varied anatomy was considered likely to cause further differences in the interfacial forces applied.

The canals were irrigated with copious amounts of 2.5% sodium hypochlorite in order to prevent canal blockage and clogging of the flutes of the files, factors which could have influenced the tactile feedback and therefore the applied forces.

The results of this study showed a large difference in the interfacial forces used by operators; however, the range of forces used by individual operators was relatively narrow. The implication was that each operator used a characteristic range of forces regardless of file type or size. There were, however, differences in the forces used for different file sizes and types, and there appeared to be a relatively consistent pattern to these differences. The larger file sizes were associated with higher interfacial forces. It is probable that this was related to the increased rigidity of the instruments. The nature of the tactile feedback resulting from the flute design and sharpness may also contribute to the forces. This view was further corroborated by the differences in interfacial forces for the different file types at size #25. The Flexofile, which is very flexible, was used with the lowest interfacial forces whereas no statistically significant difference was noted between the K-Flex and Hedström files.

These results were similar to those of Lumley et al. (2) who showed that the force exerted on canal walls during instrumentation with #15, 20 and 25 K-Flex files increased with file size.

The significance of the interfacial force in controlled root canal instrumentation is not known. Given the characteristic nature of the range of forces used by individual operators, it is interesting to speculate whether the interfacial force is a crude measure of the "skill factor" of operators. Further studies will aim to evaluate the relationship between interfacial force and the ability to shape root canals effectively.

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