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Comparative Evaluation of Buckling Resistance of Pathfinder Files: an in Vitro Study.

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ABSTRACT:

Aim: In this study, buckling resistance of D finder files, Mani K-files, Dontics K-files, M access K-files, Micromega K-files and C+ files were evaluated.
Methods: Using universal testing machine, the test endodontic files were exposed to an axially directed increasing load and the highest load that brings about an elastic displacement of 1mm in lateral direction was noted.
Results: The results show buckling resistance in decreasing order: C+ file > Micromega K file > M access K file > D finder > Dontics K file > Mani K file.
Conclusions: C+ files required the maximum load to buckle and has the highest buckling resistance than the other endodontic instruments used in this study.Taking into consideration that the buckling resistance is an important mechanical property of an endodontic instrument used for canal negotiation, C+ files showed significantly better results than the other instruments tested.
Clinical significance: Canal negotiation is the first and most important step in root canal instrumentation which provides intrinsic details about the canal complexities. The small endodontic files used for this purpose often buckle and becomes less potent to reach the apical end. Therefore, buckling resistance is an important mechanical property of an endodontic instrument used for canal negotiation ensuring success.
Key Words: Buckling resistance, endodontic treatment, endodontic files, Original research.

1. Introduction:

The clinical success of an endodontic treatment depends on the clinician's knowledge about the root canal complexities and the first step to this is the exploration of a constricted canal which is the most primitive and significant step in the root canal instrumentation. Elimination of microorganisms and their by products are crucial to ensure successful endodontic treatment.[1] Many times inability to clean the apical region of the canal or due to missed canals may lead to endodontic treatment failure.Therefore, thorough exploration of root canal is an important step that can enable the clinician to validate the number of canals, establish the unrestricted access to the most apical parts of the root canal and the anatomic apical diameter can be gauged by the clinician.[2]Also it gives the clinician a proper idea of the concept of glide path. Conceptually, glide path is a tunnel that follows the root canal orifice till the apical foramen and has a width similar to the width

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of a 10 K file. Creating a proper glide path preserves the anatomy of the root canal and also prevents any procedural errors like instrument separation or fracture.[3]Customarily, small endodontic files are desired for exploration as they validate the canal anatomy, follow the intricacies of the canal anatomy and maintain a proper glide path.

Fundamentally, endodontic files having mechanical resistance to buckling when loads are levied on them during apical progression should be used for exploration of root canals. Adequate buckling resistance can render the endodontic files potent in both locating the canal orifices as well as gaining access to the apical parts of the root canal.[4] However, these small files often buckle or develop plastic deformation under vertical loads owing to their small diameter, lack of rigidity and existence of calcification and other aberrations in the canals.

Buckling can be defined as the elastic lateral deformation of an endodontic instrument when subjected to a compressive load in the direction of its axis. [3] So as stated by the definition of buckling, any endodontic instrument which undergoes elastic or plastic deformation hampering the apical progression in the canal has low resistance to buckling. But it should be comprehended clearly that buckling is different from flexibility as the definition of the latter distinctly states flexibility as the elastic deformation of the instrument induced by the application of a load perpendicular to the axis of the instrument.

Recently many engine driven instruments are accessible for path finding purposes. Studies conducted in the past by **Keskin et al. (2018)[5], Alcade et al. (2018)[6], Santos et al. (2019)[7] and Inan & Keskin (2019)[8]** have evaluated and compared various mechanical properties of these instruments and not much attention has been given to their buckling resistance. However, conventional hand operated endodontic files are still the basic and fundamental instruments used for negotiation and exploration of the root canals and there are very scarce studies done investigating their buckling resistance. Hence the aim of this study is to evaluate the buckling resistance of D finder files, K-files, Dontics k-files, M access k-files, Micromega k-files and C+ files.

2. Materials and Methods

The following endodontic instruments were assessed in this study:
D finder files
Mani K files
Dontics K files
M access k-files
Micromega K-files
C+ files
Airotor hand piece (NSK, Japan)
BR 46 bur
Aluminium metal plate
Armamentarium/Equipment: Universal testing machine (Model no. unitest 10, acme, India.)

Methodology:
Study groups**:**

Table 1: Study groups are shown.

Group	Files	Samples
A	D finder files	18
B	Mani K-files	18
C	Dontics K-files	18
D	M access K-files	18
E	Micromega K-files	18
F	C+ files	18

This study compared the buckling resistance of D finder files, Mani K-files, Dontics K-files, M access K-files, Micromega K-files and C+ files. Buckling resistance (n = 18) was measured by connecting the instrument handle to the device, and then placing the instrument tip in a small cavity made in the metal plate

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as illustrated in Figure 1 and the Figure 2 represents bucking of endodontic instrument.

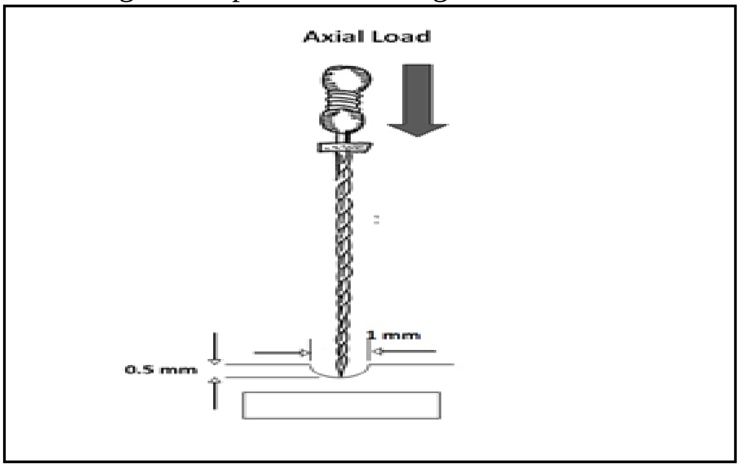

Figure 1: Diagrammatic representation of endodonticinstrument.

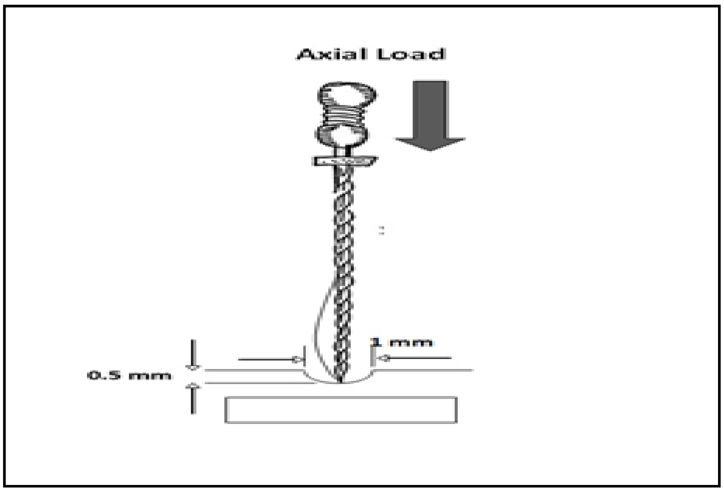

Figure2: Diagrammatic representation of bucking for endodontic instrument.

Then, restraining the file tip in a point location, the file was loaded at the crosshead speed of 1.0 mm/s in the axial direction of the shaft as shown in Figure 3.

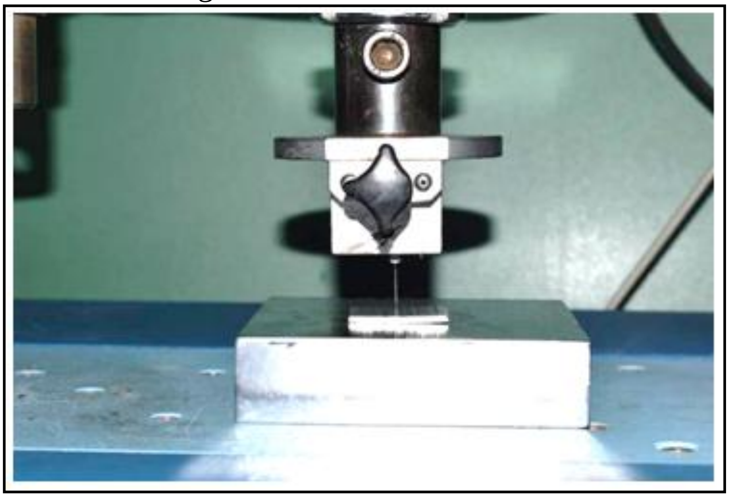

Figure 3: Instrument loaded in the Universal Testing Machine.

During the loading and the file's deflection, the axial load was plotted and the maximum load was defined as the buckling resistance as shown in Figure 4.

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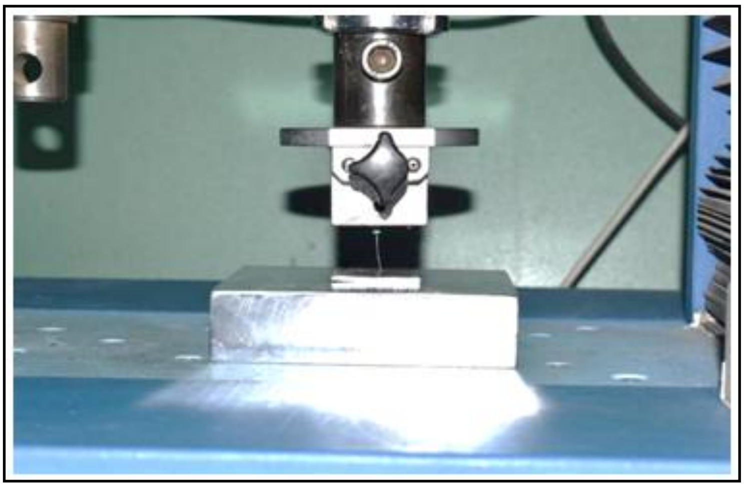

Figure 4: Buckling of instrument under Universal Testing Machine.

This was repeated for all the samples from the six groups.

Statistical Analysis:
All data was entered into a Microsoft office excel (version 2013) in a spreadsheet and checked for errors and discrepancies. data analysis was done using windows based 'medcalc statistical software' version 13.3.1 (medalc software bvba, Ostend, belgium; http://www.medcalc.rorg; 2014). Data were statistically evaluated by kruksalwallis test and post hoc tukeyhsd test using spss 16 software. Significance level using ANOVA test is shown in Table 2.

Table 2: Significance level using ANOVA test.

Source of variation	Sum of Squares	DF	Mean Square
Between groups (influence factor)	23.7574	5	4.7515
Within groups (other fluctuations)	0.2353	102	0.002307
Total	23.9927	107	

F-ratio	2059.910
Significance level	P < 0.001

Comparison of buckling resistance between the six groups for variability using the Kruskal-Wallis test (non-parametric ANOVA) is shown in the Table 3 and Table 4 shows Post-hoc Dunn's test used for pairwise comparisons.

Table 3: Comparison of buckling resistance between the six groups for variability using the Kruskal-Wallis test (non-parametric ANOVA).

Test statistic	93.0872
Corrected for ties Ht	94.0730
Degrees of Freedom (DF)	5
Significance level	P < 0.000001

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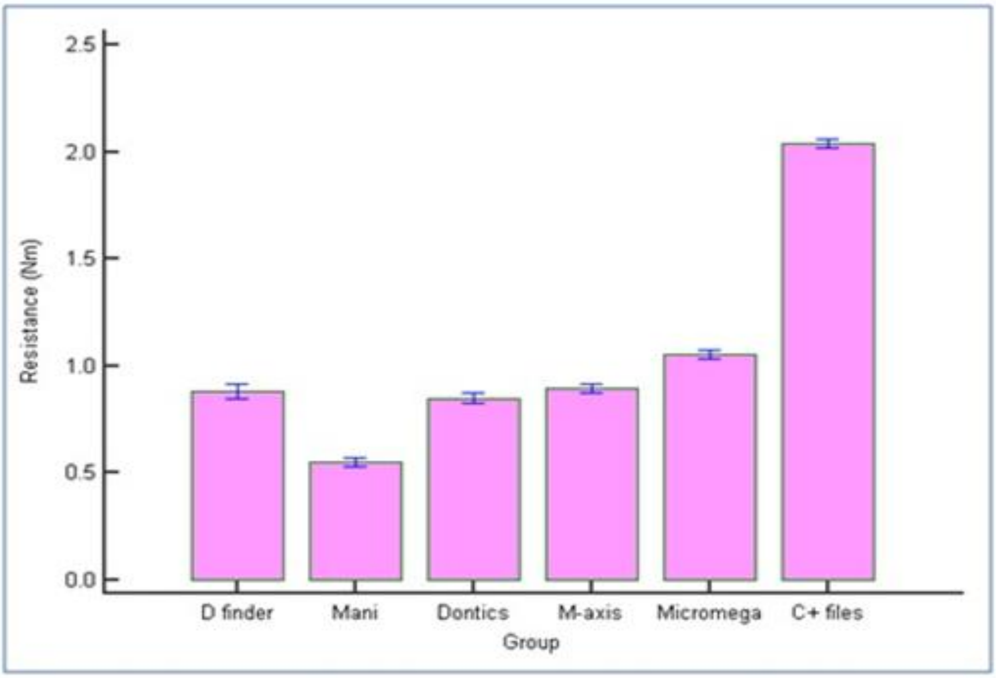
Table 4: Post-hoc Dunn's test used for pairwise comparisons.

Factor	N	Average Rank	Different from factor nr (P<0.05)
(1) 1	18	46.03	(2)(5)(6)
(2) 2	18	9.50	(1)(4)(5)(6)
(3) 3	18	38.72	(5)(6)
(4) 4	18	52.33	(2)(6)
(5) 5	18	80.92	(1)(2)(3)
(6) 6	18	99.50	(1)(2)(3)(4)

Multiple comparison graph of buckling resistance of endodontic instruments is shown in Graph1.



Graph 1: Multiple comparison graph of buckling resistance of endodontic instruments.

3. Results:

The mean values of buckling resistance for tested three groups were given in table 5.

Table 5: Buckling resistance of endodontic instruments.

Instrument	Size	Do	taper (mm)	mean load
D finder files	10	0.10	0.02	0.88±0.07*
Mani K files	10	0.10	0.02	0.55±0.03*
Dontics K files	10	0.10	0.02	0.85±0.04*
M access K files	10	0.10	0.02	0.89±0.04*
Micromega K files	10	0.10	0.02	1.05±0.04*
C+ files	10	0.10	0.04(first 4mm from the tip) 0.02(rest of the shaft)	2.03±0.04*

*mean ± standard deviation.

Statistical analysis showed a highly significant difference in the maximum load necessary to buckle the six instrument tested (P<0.001). The highest values were observed for C+ files and lowest were observed for

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Mani K files.

4. Discussion:

One of the most challenging situationsthat an endodontist faces is exploration of a constricted curved canal. Procedural accidents like perforation and ledges happen during exploration of these constricted curved canals which makes negotiation of these narrow canals strenuous and stressful task. [9]

Recently root canal preparations are done using rotary endodontic files but clinicians need to prepare the initial glide path before inserting the rotary endodontic files into the canal to prevent fracture of the instrument due to torsional stress.[10]

The root canal can be narrow and can consist of calcifications and other aberrations which can hinder the smooth progression of endodontic files to create a glide path. So, the endodontic files used for exploring and negotiating the canal should have a smaller dimension and higher buckling resistance so as to remove the calcification and progress towards the apical end. Buckling resistance is a significant attribute enabling the path finding instrument to reach the root canal apex negotiating the canal curvatures, constrictions and any anatomic aberrations.[9]

Majority of the K type conventional endodontic instruments (size iso 06 and 08) exhibit poor buckling resistance which makes them less potent to negotiate constricted curve canals till the apical end.[2]Hence size iso 10 is used in this study. In this study, the endodontic instruments tested are similar in size but different in taper and crossection and they all are recommended for negotiation of root canal. Hence, they are compared in this study. Although all these endodontic instruments are indicated for canal negotiation, very few studies are done investigating their buckling resistance.

Previous studies have stressed on the importance of investigating the buckling resistance wherein assay was used to test the instrument deflection in which load was applied perpendicular to the axis of instrument.

Lopes et al. (2012)[11] and **Kwak et al. (2014)**[12] in their study compared buckling resistance of pathfinder files including C+ files by applying load along the long axis of the instrument. This shall be because forces are usually applied along the long axis of the instrument during canal exploration and instrumentation.

In the present study, the buckling resistance of the instrument were performed by applying an axial load to the instrument. This makes the study easy to perform and reproducible. From the results obtained, C+ file has the highest buckling resistance and it is due to its larger 4% taper along the 4mm apical length. Hence, the C+ file has a larger area and stronger core to resist buckling of the endodontic files.

D finder files which have D shaped crossection has buckling resistance similar as compared to Dontics K-file and M access K-file having square crossection. **Khasnis Sandhya et al (2018)**[13]in their study stated that the pitch and number of flutes of the instrument should also be considered as it influences the flexibility thereby affecting the buckling resistance. D finder files have high pitch. Higher the pitch, lesser the flutes and lesser the buckling resistance.[14]

Micromega K-files has a better buckling resistance when compared to D finder files, Mani k-files and Dontics k-file but definitely has less buckling resistance than C+ files. Mani K-files showed the least buckling resistance with greatest distortion. One of the reasons for this can be machinery defects. Machinery defects are the defects that occur in a file during manufacturing process. It causes corrosion propagation that eventually cause breaking of file during practice.[15]**Gutmann J L et al (2011)**[16]suggested electro polishing creating a homogeneous oxide layer, with an associated reduction in surface defects and stress, resulting in omission of the machinery defects in files.

According to a study done by **Izadi Arash et al(2016)**[17], Mani K files has shown highest machinery defects as compared to the other endodontic files used in their study. And also, some files are made softer than the other endodontic files as they are produced with the aim of creating a glide path. This can also be a reason for low buckling resistance of Mani K-files.

The results obtained can be explained by the differences in taper, sizes and the type of alloy used for manufacturing of this alloys. C+ files showed a greater resistance to buckling than other instrument tested in this study. This can be attributed to the fact that C+ files has a larger taper of 4% along the apical 4mm length so it has larger area and stronger core to resist buckling. Other stainless-steel instruments in this study have low modulus of elasticity as compared to the C+ files and hence the have lesser buckling resistance than the latter. Thus, in this study null hypothesis is rejected as the buckling resistance is not

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similar with at least two of the six files. Hence there is significant difference in the maximum load necessary to buckle the six instruments tested. Limitations of this study includes the fact that corrosion resistance, quality and properties of stainless steel used in the manufacturing of these endodontic files can also influence the buckling resistance. Similar studies have been done by **Lee et al (2011)**[18] on geometric characteristics and alloy of instruments for shaping procedure for rotary endodontic files and therefore, further mechanical and clinical test are recommended to verify how these properties influence buckling resistance of conventional hand operated endodontic files. In future range of strategies like modifications in electro polishing, ion implantation and file twisting will be attempted to enhance the buckling resistance of endodontic instruments.

5. Conclusion:

Within the experimental conditions of the study, buckling resistance of six endodontic instruments of different brands used for canal negotiation were compared and we may conclude as:

C+ files required the maximum load to buckle and has the highest buckling resistance than the other endodontic instruments used in this study due to larger taper of 4% along the apical 4mm length so it has larger area and stronger core to resist buckling.

6. Clinical Significances:

Canal negotiation is the first and most important step in root canal instrumentation which provides intrinsic details about the canal complexities. The small endodontic files used for this purpose often buckle and becomes less potent to reach the apical end. The root canal can be narrow and can consist of calcifications and other aberrations which can hinder the smooth progression of endodontic files to create a glide path. So, the endodontic files should have a higher buckling resistance so as to remove the calcification and progress towards the apical end. Therefore, buckling resistance is an important mechanical property of an endodontic instrument used for canal negotiation ensuring success.

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