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Dentinal resistance to compressive forces after root canal instrumentation with three different machine endodontics systems

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RESEARCH

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ABSTRACT

Background
The association between the occurrence of microfractures and vertical root fractures has not been proven in published studies. One of the ways of trying to examine the influence of certain procedures on the resistance of the tooth to the action of occlusal forces is to subject the samples to fracture resistance testing by forces directed at the tooth or a specimen at different angles or by measuring that force on the root cross-sectional surface compressive strength.

Aims
This study aims to examine dentinal resistance to compressive forces after root canal instrumentation with three different machine endodontics systems.

Methods
In order to examine the effect of instrumentation on the resistance of root dentin to the action of compression and compressive forces, teeth were divided in three groups and were instrumented with three different endodontics systems. The samples were subjected to compressive strength testing. Two forces were recorded: maximum force and breaking force.

Results
The results of the variance analysis show that there is no difference in breaking force between groups ($p=0.151$), but the difference is statistically significant between sections ($p=0.001$). The values of breaking forces in the cervical part are on average 25 per cent lower.

Conclusion
When comparing the apical, medial and cervical part of the tooth, the medial part of the tooth has the highest values of breaking force and the apical part has slightly lower values. The values of breaking forces in the cervical part are on average 25 per cent lower.

Key Words
Dentinal resistance, compressive forces, machine endodontics

What this study adds:

1. What is known about this subject?
The association between the occurrence of microfractures and vertical root fractures has not been proven in published studies.

2. What new information is offered in this study?
This study examines dentinal resistance to compressive forces after root canal instrumentation with three different machine endodontics systems.

3. What are the implications for research, policy, or practice?
When comparing the apical, medial and cervical part of the tooth, the medial part of the tooth has the highest values of

breaking force and the apical part has slightly lower values.

Background

The association between the occurrence of microfractures and vertical root fractures has not been proven in published studies.[1] One of the ways of trying to examine the influence of certain procedures on the resistance of the tooth to the action of occlusal forces is to subject the samples to fracture resistance testing by forces directed at the tooth or a specimen at different angles or by measuring that force on the root cross-sectional surface compressive strength.[2-5] The samples can be prepared differently. One way is to immerse the root of the whole tooth or its crowned root part in acrylate and subject it to the force of breaking. The other way is to cut the cross sections of individual parts of the root and test the compressive strength of the sample. In the first procedure, in addition to the instrumentation of root canals,[4,5] other parameters can be included in the research, such as the method of rinsing root canals during instrumentation,[6,7] different techniques of filling canals,[8,9] type of intracanal filling,[10,11] type of upgrades,[12-14] apicectomy techniques[15] and crown restoration by various direct and indirect procedures.[16] In the second procedure, before determining the force at the breaking point, the area of a particular sample is determined so that this value can be included in the calculation of the compressive strength of the sample. Both methods have drawbacks due to the difficulty of standardizing the sample.

Method

In order to examine the effect of instrumentation of different kinematics on the resistance of root dentin to the action of compression and compressive forces, samples examined by micro CT analysis for the existence of microfractures (10 from each group) were horizontally cut with Isomet 1000 (Buehler, Lake Bluff, IL, USA) in three parts: apical, middle and coronary part. Teeth were divided in three groups. One group was instrumentated with rotating system (ProTaper next endodontics system, PTN), another one with reciprocitating system (Reciproc blue, RB), and the third group with vibrating system (Self adjusting file, SAF). The thickness of the cut was set at 3mm, but due to the loss of part of the mass during the cutting process, the samples were ultimately approximately 2.3mm thick.

A total of 90 incisions were obtained. The obtained samples were recorded with a stereomicroscope with a standard millimeter scale and the area of each sample was calculated using computer program ImageJ Win Java 8 (National Institutes of Health, USA). Firstly, the total cross-sectional area of the sample was calculated and then the value of the central instrumental part for the coronary, middle and apical part was subtracted from it.

The samples were subjected to compressive strength testing using a universal testing machine AGS-X, Shimadzu (Shimadzu, Japan), with maximum force of 10kN. Testing was performed at room temperature, 22˚C, with humidity level of ~45 per cent with computer program TrapeziumX. The test jaws consist of a lower flat plate and an upper jaw with the shape of a spike. After pre-experiments with spikes with tip diameter of 1mm, 2mm and 4mm, specially designed for this research, it was decided to use the upper pressure plate (spike) with a diameter of 1mm in the experiment because use of spikes of larger diameter did not lead to cracking. The samples were placed directly under the spike and subjected to vertical force at a speed of 0.5mm/s to determine the resistance to fracture. The device was programmed to record a sudden change in force that indicated fracture of the sample. Two forces were recorded: maximum force and breaking force. The obtained value is included in the calculation together with the surface of the sample and the obtained ratio of force and surface area of the sample segment is needed to cause it to fracture.

Results

The results of the variance analysis show that there is no difference in breaking force between groups ($p=0.151$), but the difference is statistically significant between sections ($p=0.001$). The combined effect is not significant, meaning that the differences between sections are similar for each group ($p=0.818$) (Figure 1.)

The results of variance analysis show that there is no difference in maximum force between groups ($p=0.492$), but the difference is statistically significant between sections ($p<0.001$). The combined effect is not significant, meaning that the differences between sections are similar for each group ($p=0.958$).

Upon comparison of different instrumentation methods, the SAF and RB groups have almost the same values of breaking forces. The difference is evident in the last PTN group, although not statistically significant (Table 1.)

Upon comparison of the apical, medial and cervical part of the tooth, the medial part of the tooth has the highest values of breaking force and the apical part has slightly lower values. The values of breaking forces in the cervical part are on average 25 per cent lower (Table 2.)

Discussion

Dentinal resistance to fracture after root canal treatment depending on the instrumentation technique in this study was examined by dividing the roots into three parts, cervical, middle and apical, calculating the dentin surface and then the samples were subject to compression force. The method of testing root resistance or root cross-section to fracture under compressive forces is influenced by many factors that can affect the outcome: tooth type, donor age, volume, amount of secondary dentin, individual chemical composition variability and tooth histological structure. This study was conducted on premolars of patients aged 16–20 years, with equal number of male and female patients. Also, the storage time of the samples was up to two months which according to Aydin et al.[17,18] is enough to preserve the mechanical properties of dentin and enamel. Although the teeth were cut with a precision saw to a 3mm thick incision, the thickness of the cuts was still not completely uniform, which is explained by the inability of complete control over the procedure and the uneven tissue loss in the cutting process itself. Therefore, the cuts were on average about 2.5mm thick. This type of test differs from studies that used the entire tooth to measure fracture resistance, where test samples were immersed in acrylate and coated with a silicone impression coating simulating periodontal ligament,[4,5] which is subject to high sample variability due to the inability to standardize dentin volume in sample. Studies have shown that fatigue resistance is higher if teeth were coated with silicone rubber simulating periodontal ligament during testing.[17] In order to partially reduce the limitation of the method and in the attempt to bring the samples relative to the dentin surface, the samples were physically divided into three parts and the method used was described in the 2012 dissertation by Nguy.[19] According to Lertchirakaran et al. the disadvantage of this method is the removal of the effect of root curvature on the resistance to stress forces, the most important factor in the distribution of forces, even more important than the external morphology of the tooth. In this study, the maximum force and the fracture force, i.e., the breaking force, were measured. The differences between these two measurement points speak of the characteristics of the dentin material. Brittle materials require a large amount of stress (more force is needed for the material to crack), but they have a very small difference between the maximum and breaking force. Such materials are strong, resistant to deformation, but as they are not tough enough, they are fragile. For these materials, it is specific that the maximum force and the breaking force are at the same point. Tough materials are more resistant to cracking, i.e., their ability to deform prevents the material from cracking. Compared to brittle materials, they are less strong but more flexible and hard. Variability in brittleness and deformability properties in some specimens are expressed in different tooth cross sections. There are differences between sections A, M, and C and some samples are less deformable and some slightly more.[20]

Conclusion

Upon comparison of different instrumentation methods, the SAF and RB groups have almost the same values of breaking forces. The difference is evident in the last PTN group, although not statistically significant. It is to be expected that the difference between the groups would become more evident in a larger number of samples. Of course, it is to be expected that this difference would not be as great as the difference between the different cuts. In the following works, a correction of the test setup should be made, so that the strengths (compressive and breaking strengths) of a particular tooth cross section can be calculated, which leads to the way in which the surface will be calculated.

When comparing the apical, medial and cervical part of the tooth, the medial part of the tooth has the highest values of breaking force and the apical part has slightly lower values. The values of breaking forces in the cervical part are on average 25 per cent lower. The finding is somewhat consistent with that of Nguy who, comparing the influence of the conicity of the instruments used on fracture toughness, found that the apical region is the most resistant to the action of compressive forces.

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PEER REVIEW

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CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

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None

Figures and Tables

Figure 1: Graphic representation of the analysis of fracture force variance between groups (SAF - Self Adjusting File, RB - Reciproc Blue, PTN - ProTaper Next) at the apical (A), medial (M) and cervical (C) levels

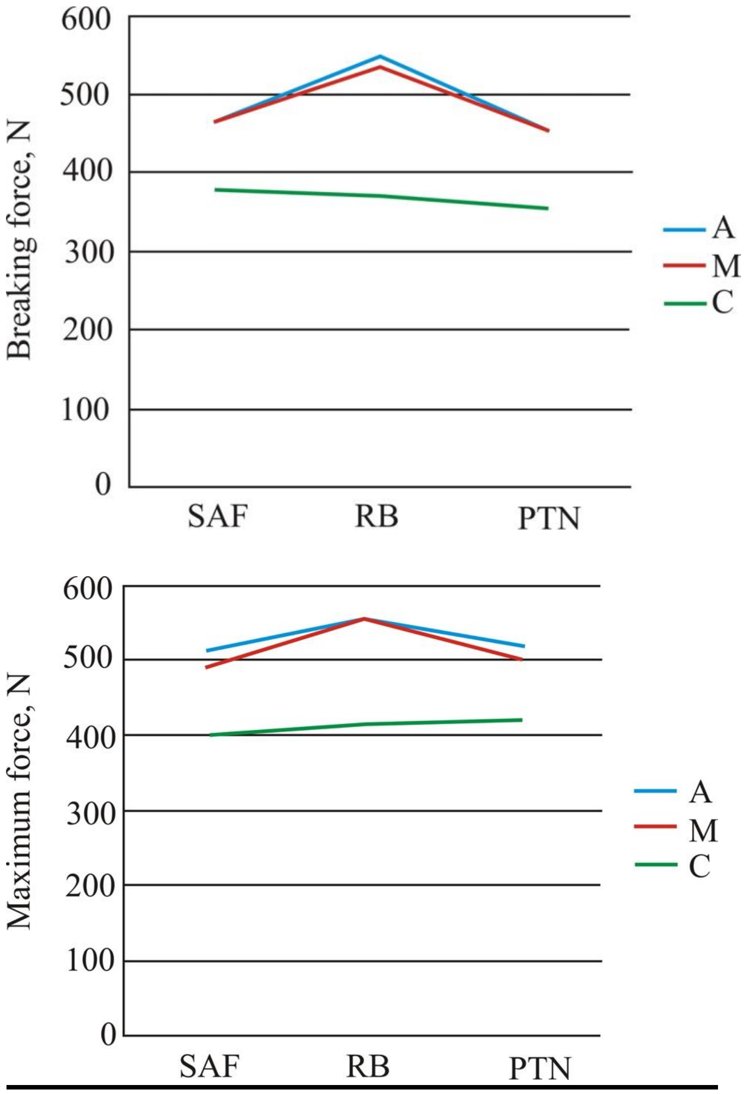

Table 1: Values of descriptive statistical analysis of the examined groups in relation to the area and thickness of dentin, maximum and breaking forces at which sample breaks

	Dentine Surface Area/ mm^2	Dentin Thickness/ mm	Max Force/ N	Breaking Force/ N	Difference
Median Value SAF Group	21.43	2.38	508.75	473.12	0.29
Standard Deviation SAF Group	10.886	0.406	121.805	128.802	0.081
Max Value SAF Group	39.85	3.50	708.97	651.91	0.52
Min Value SAF Group	6.92	1.58	213.41	200.14	0.18
Median Value RB Group	12.54	2.40	508.13	485.57	0.28

Standard Deviation RB Group	10.776	0.454	133.386	146.512	0.150
Max Value RB Group	52.55	3.92	727.36	727.36	0.92
Min Value RB Group	5.09	1.38	214.79	214.79	0.16
Median Value PTN Group	12.93	2.51	480.91	419.15	0.33
Standard Deviation PTN Group	11.544	0.417	120.602	127.463	0.132
Max Value PTN Group	46.51	3.60	650.04	645.61	0.67
Min Value PTN Group	2.21	1.92	196.64	172.15	0.16

Table 2: Values of descriptive statistical sample analysis for the part of root where testing was performed with regard to the surface area and dentine thickness, maximum and breaking forces at which sample breaks

Apical Section	**Dentin Surface Area/ mm^2**	**Dentin Thickness/ mm**	**Max Force/ N**	**Breaking Force/ N**	**Difference**
Median Value A	11.39	2.34	532.68	490.26	0.27
Standard Deviation A	7.543	0.277	100.169	126.269	0.111
Max Value A	25.82	3.18	727.36	727.36	0.67
Min Value A	2.21	1.88	321.60	200.14	0.16
Medial Section					
Median Value M	16.21	2.51	547.34	513.17	0.31
Standard Deviation M	12.969	0.341	118.631	125.192	0.156
Max Value M	52.55	3.44	708.97	690.93	0.92
Min Value M	2.27	1.82	196.64	196.64	0.16
Cervical Section					
Median Value C	18.07	2.46	415.74	371.45	0.32
Standard Deviation C	12.928	0.592	114.087	117.225	0.109
Max Value C	48.25	3.92	586.00	586.00	0.59
Min Value C	3.69	1.38	213.41	172.15	0.16