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The Effect of Glide Path Establishment on Stress Generation During Root Canal Instrumentation: An Acoustic Analysis

Rehber Yol Oluşturmanın Şekillendirme Sırasında Oluşan Streslere Etkisi: Bir Akustik Analiz Çalışması

ABSTRACT

Objectives:
This aqoustic analysis study aimed at evaluating the effect of glide path preparation on sound wave propagation due to stress in resin blocks during root canal preparation.

Material and Methods:
Endo training resin blocks with J shaped canals were randomly divided in to 2 groups according to glide path establishment(with or without) (n =12) For the glide path establishment group, the glide path was prepared using WaveOne Gold Glider. All samples were shaped with WaveOne Gold. During the instrumentation with WaveOne Gold, sound signal levels were recorded on computer using piezoelectric prob. The data were analyzed statistically using Mann-Whitney U tests at a significance level of $P < 0.05$.

Results:
Sound signal levels were significantly different between groups ($P < 0.05$). The signal levels in WaveOne Gold with glide path group lower than in WaveOne Gold without a glide path group ($P < 0.05$).

Conclusion:
Our results show that the creating a glide path can decrease the amount of stress during shaping with WaveOne Gold. The establishment of glide path before root canal preparation appears to be apporiate for safely shaping the canal.

ÖZ

Amaç:
Bu akustik analiz çalışmasının amacı, rehber yol oluşturmanın kök kanallarının şekillendirmesi sırasında rezin bloklarda stresten kaynaklı oluşan ses dalgalarının yayılımına olan etkisini değerlendirmektir.

Gereç ve Yöntemler:
J şekilli endo rezin blokları rehber yol oluşturulacak ve oluşturulmayacak gruplar olmak üzere 2 gruba ayrıldı. Rehber yol oluşturulan grupta rehber yol şekillendirmesi WaveOne Gold Glider ile yapıldı. Bütün örneklerin şekillendirme işlemi WaveOne Gold Primary eğesi ile bitirildi. WaveOne Gold Primary ile şekillendirme sırasında oluşan ses sinyal seviyeleri piezoelektrik diskler kullanılarak bilgisayara kaydedildi. Veriler Mann-Whitney U testleri kullanılarak P <0 .05 anlamlılık düzeyinde istatistiksel olarak analiz edildi.

Bulgular:
Ses sinyal seviyeleri gruplar arasında anlamlı derecede farklıydı. ($P < 0.05$) Öncesinde rehber yol oluşturulan WaveOne Gold grubunda ses sinyal seviyeleri rehber yol oluşturulmayan WaveOne Gold grubuna göre daha azdı. ($P < 0.05$)

Sonuç:
Sonuçlarımız gösterdi ki rehber yol oluşturmak WaveOne Gold ile şekillendirme yaparken oluşan stresi azaltabilir. Kök kanal şekillendirmesinden önce rehber yol oluşturulması daha güvenilir bir şekillendirme yapmayı sağlar.

Anahtar Sözcükler:
Rehber yol, Waveone gold glider, Stres birikimi, Akustik analiz

INTRODUCTION

The preparation of root canals using rotary nickel titanium (NiTi) files has many advantages over their preparation with stainless steel (SS) files. The preparation with NiTi files is performed in a shorter time, the physician is less tired and procedural mistakes that may occur during the preparation are minimized (1-3). However, in addition to these advantages, NiTi files cause a stress between the file and root canal walls that can result in a fracture of the file and/or crack formation in the root canal dentine (4). The risk of the file fracturing is greater, especially in curved root canals (5,6). In addition, the width of the contact surface between the cutting edge of the file and the canal wall affects this stress (7,8). On the other hand, crack formation may be observed in the dentine because of the increased stress from the root canal walls due to the canal preparation (9,10). Therefore, the stresses occurring on the files and canal walls should be minimized during the preparation. Studies (11-14) have shown that creating a glide path mechanically or manually reduces the procedural mistakes that can result from these stresses, enabling a more reliable preparation.

Today, many different NiTi file systems that allow creating a glide path are produced. The most recently developed one is WaveOne Gold Glider (Dentsply Maillefer, Ballaigues, Switzerland). It is produced with gold wire metallurgy, and the file has a cone angle beginning with a 2% taper at the tip that reaches 6% at the coronal section. The tip diameter of the file is 0.15 mm. Gold wire technology enhances the flexibility of the file and increases its resistance to rotary fatigue compared to non-heat treated files. The manufacturer recommends creating a glide path with WaveOne Gold Glider before canal preparation with the WaveOne Gold files. In a study measuring simultaneous torque accumulation during canal preparation, it has been shown that torque-related stress occurs in parallel with the advancement of the file in each pecking movement during preparation with WaveOne Gold files and that this stress is higher for cases in which a glide path is not created (15).

Several studies (16,17) evaluated the torque production on the file occurring during root canal preparation by measuring the stress on the canal walls. However, Burklein, et al. (18) reported that pure forces cannot be determined by a multi-component measuring device, especially in the presence of simulated periodontal ligament. Another limitation of previous studies was that although the stress and strain concentrations in the inner dentin wall and the friction of the instruments with the canal wall might play primary roles in crack formation (19), most of the previous studies assessed the strain values induced by the canal shaping on the external surface of the root (17).

The term acoustic is used to define the work of an elastic wave or simply to define sound frequency ranges. Elastic vibrations and acoustic waves are widely used in various engineering devices and for non-destructive testing (NDT). For example, strong ultrasonic vibrations are used for local fractures of fragile and high strength materials (ultrasonic crushing), dispersion (crushing of solid or liquid bodies in any environment, e.g., oils in water), coagulation (amplification of the particles of a substance such as smoke) and other purposes (20). In the present study, piezoelectric acoustic detection was utilized to determine stress concentrations on root canal walls during preparation.

In the literature, there is no acoustic analysis study that evaluates the propagation of acoustic waves occurring due to stress in the resin blocks during the advancement of the file in root canal preparation. The objective of this acoustic analysis study was to evaluate the effect of glide path preparation on stress formation in the root canal walls of resin blocks.

MATERIAL and METHODS

Preparation of Artificial Canals

Twenty-four J-shaped artificial resin blocks with 0.02 cone angle, 0.15 mm apical diameter and 16 mm working length were used (Dentsply Maillefer). A #10 K file was inserted into the canal within the working length, and canal openings were checked.

The J-shaped resin blocks were randomly divided into 2 groups: one group with a glide path created with WaveOne Gold Glider (WOGG + WOG) and one without a glide path (WOG). All preparation processes were performed with an X-Smart Plus device (Dentsply Maillefer) using WaveOne software. The preparations were completed in both groups using a WaveOne Gold Primary file. During the preparation, the file was advanced along the working length in three stages with reciprocal motions employing a light apical pressure. The file was withdrawn after each reciprocal motion, debris on the file was cleaned and the artificial canals were irrigated with saline.

These 3 stages were named coronal, middle and apical on the blocks, and data were separately recorded for each stage. A new file was used in each acrylic block, and all preparation stages were performed by the same operator.

Experimental setup and data transfer

In the current study, we used a piezoelectric element (sensor) for detecting the acoustic waves that were produced by the rotary file in the resin blocks during canal preparation. Piezoelectricity is the process of converting mechanical energy into electrical energy or vice versa. Usually, piezo elements such as lead, zirconium and titanium are prepared to produce piezoelectricity. Data can be obtained for the voltage that will be created on piezoelectric elements. For this study, piezo elements suitable for the size of the resin blocks used were first prepared. The poles of the piezo element were soldered to an AUX cable with a 3.5 mm jack at one end. The piezo element was then connected to the test block and linked to the computer's sound card using the prepared cable. Sound waves and vibrations that occurred on the block during the preparation caused voltage alterations on the piezo element according to the piezoelectric principle, and these voltage changes were recorded as an audio signal on the computer via an audio recording program. (Figures 1 and 2)

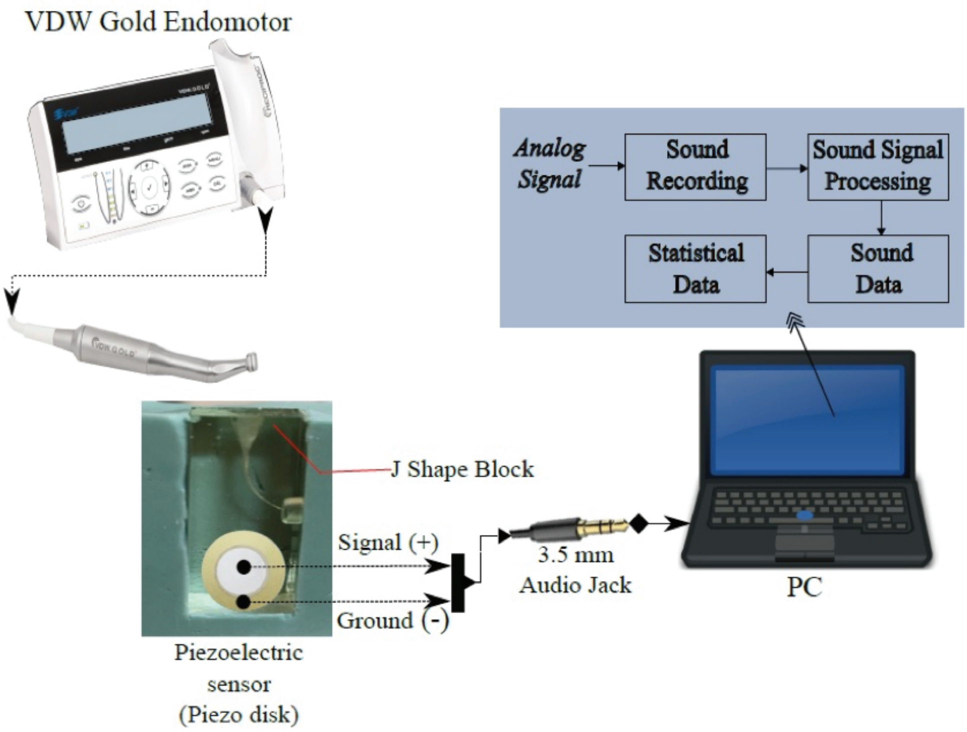

Figure 1. The experimental setting for in vitro the acoustic analysis.

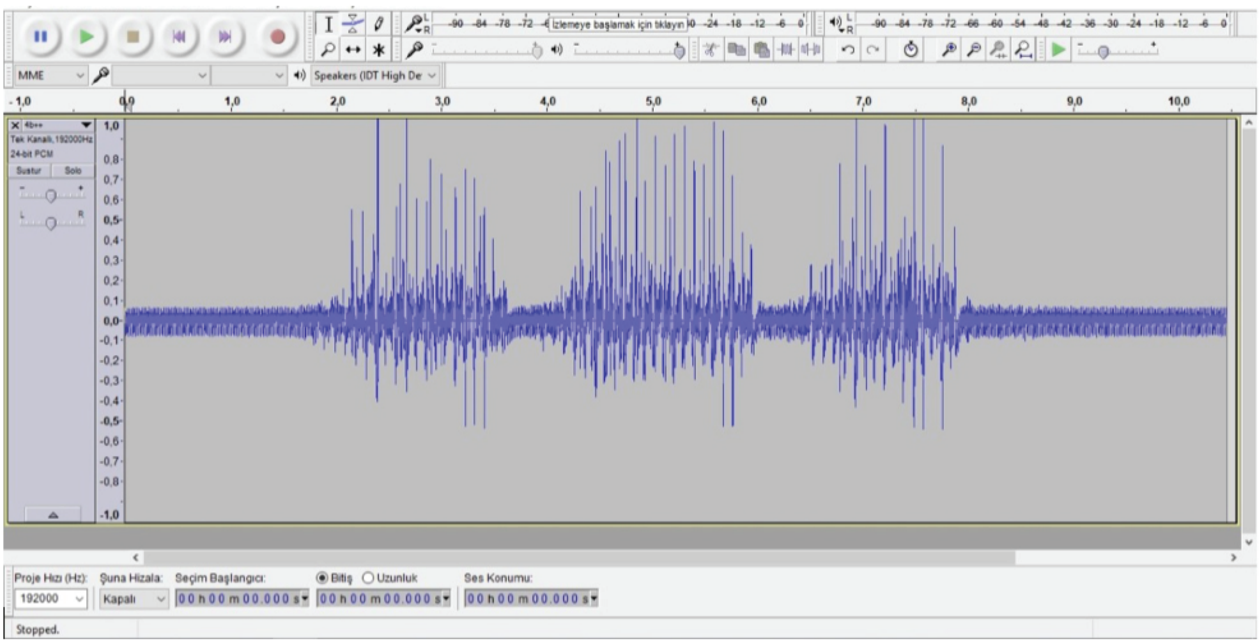

Figure 2. A screen image during data transfer while root canal instrumentation.

These time-dependent data were then transformed into numerical matrices, and the data were recorded in files with a .txt extension using Audacity software. Sound is fundamentally a pressure wave. The low and high pressure regions formed by this wave are the main physical phenomena of the sound transmission and direction. This physical property is represented by processing high pressure as positive numerical values and low pressure as negative numerical values in audio recording. Both the positive and negative numerical values represent stress concentration levels during preparation. In this study, the direction of sound was not significant because of the small dimensions of the blocks; however, to detect even the smallest fluctuations in sound, the negative and positive data were both evaluated.

Statistical analysis

The statistical analysis of the data obtained was performed using SPSS (Statistical Package for Social Sciences for Windows 15.0, Chicago, IL, USA) software. Since the data obtained were not normally distributed, Mann-Whitney U and Kruskal-Wallis tests were used for intergroup and intragroup analysis, respectively. The significance level was set at $p=0.05$.

RESULTS

Peak voltage values were evaluated for stress levels during preparation. Table 1 shows the distribution of the number of peak voltage values obtained from the acoustic test according to group. In the positive field, the analyzed peak voltage values for the WOG group were 25000, 27500 and 16500 for the coronal, middle and apical sections, respectively. For the WOGG + WOG group, they were 16500, 19500 and 6700. In the negative field, the analyzed peak voltage values for the WOG group were 24000, 27500 and 16500 for the coronal, middle and apical sections, while for the WOGG + WOG group, they were 20500, 15500 and 6700 (Table 1).

The mean voltage values that occurred during the canal preparation are shown in Tables 2 and 3. Intergroup analyses revealed significantly lower stress (voltage) values for the WOGG + WOG group than for the WOG group in all sections ($P < 0.001$). In the coronal section, the mean stress values were 0.33014 and 0.43452 for the WOGG+WOG and WOG groups, respectively ($P < 0.001$). In the middle section, the mean stress value was 0.29402 for the WOGG + WOG group and 0.47829 for the WOG group ($P < 0.001$). In the apical section, the mean stress values were 0.30465 and 0.43344 for the WOGG+WOG and WOG groups, respectively ($P < 0.001$).When comparing negative field mean voltage values, there were significant differences between the groups for all sections. The mean voltage values were significantly lower in the WOGG+WOG group than in the WOG group in the coronal, middle and apical sections ($P < 0.001$). In the coronal section, the mean stress values were 0.27133 and 0.29640 for the WOGG+WOG and WOG groups, respectively ($P < 0.001$). In the middle section, mean stress value was 0.27910 for the WOGG + WOG group and 0.32123 for the WOG group ($P < 0.001$). In the apical section, the mean stress values were 0.27157 and 0.29919 for the WOGG+WOG and WOG groups ($P < 0.001$) (Tables 2 and 3).

Table 1. The mean voltage values during root canal preparation

Groups	Coronal		Middle		Apical	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
WOG	0.43452	0.000848	0.47829	0.001083	0.43344	0.001323
WGG +WOG	0.33014	0.001529	0.29402	0.001289	0.30465	0.002039

SD: Standard Deviation

Within the same column, values with the same superscript uppercase were not statistically different at P = 0.05. Within the same row, values with the same superscript lowercase were not statistically different at P = 0.05

Table 2. The mean voltage values (V) in the positive field during root canal preparation

Groups	Coronal		Middle		Apical	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
WOG	0.43452^{Aa}	0.000848	0.47829^{Ab}	0.001083	0.43344^{Ac}	0.001323
WGG +WOG	0.33014^{Ba}	0.001529	0.29402^{Bb}	0.001289	0.30465^{Bb}	0.002039

SD: Standard Deviation

Within the same column, values with the same superscript uppercase were not statistically different at P = 0.05. Within the same row, values with the same superscript lowercase were not statistically different at P = 0.05

Intragroup analyses revealed that there were significant differences among the coronal, middle and apical levels in the WOG and WOGG +WOG groups in terms of stress level (Tables 2 and 3).

Table 3. The mean voltage values (V) in the negative field during root canal preparation

Groups	Coronal		Middle		Apical	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
WOG	0.29640^{Aa}	0.000621	0.32123^{Ab}	0.000564	0.29919^{Aa}	0.000862
WGG +WOG	0.27133^{Ba}	0.001065	0.27910^{Ba}	0.001337	0.27157^{Ba}	0.001742

SD: Standard Deviation

Within the same column, values with the same superscript uppercase were not statistically different at P = 0.05. Within the same row, values with the same superscript lowercase were not statistically different at P = 0.05

In the WOGG + WOG group, significantly higher stress values were recorded in the coronal section than in the middle and apical sections ($P < 0.001$). However, there was no significant difference between the middle and apical sections ($P > 0.05$). In the WOG group, there was a significant difference among the coronal, middle and apical sections.

DISCUSSION

Studies (11,12,21) have shown that a glide path should be created before preparation using reciproc or rotary NiTi glide path files in order to achieve a more effective and reliable preparation. A glide path reduces the risk of file fractures in the canal as well as the effects of the torsional stress level (4,8,21). In particular, single file systems may cause higher torque accumulation compared to multiple file systems (22). The file contacts more wall surface as it is advanced within the canal, and the file and canal walls are exposed to higher stress especially in the curved sections of the canal (15).

In the present study, we compared the levels of acoustic waves that occurred in artificial canals by advancement of the file in the canal between groups with and without a glide path. According to the results of this study, the voltage values occurring as a result of the acoustic waves during the canal preparation were found to be lower in the positive field and higher in the negative field at all 3 sections in the WOGG+WOG group than in the WOG group. This means that, at all levels, less stress in the canal walls occurred in the WOGG+WOG group than in the WOG group. These findings are in accordance with previous studies (15,16) that evaluated the effect of glide path preparation on stress formation on root canal walls. This can be explained by the fact that the canal volume before root canal preparation process can influence the torque accumulation and stress that occur during the preparation. The tip portion of WaveOne Gold Glider glide path reciproc file begins with a cone angle of 2%, increasing to a 6% angle in the coronal portion. The structure of these files, which becomes wider toward the coronale, is used to create a glide path before the preparation process; it can provide the file a much easier advance into the canal. This produces less strain in the canal and lower voltage levels due to vibration-related acoustic waves created by preparation shaping instruments. On the other hand, Berutti et al. (17) used Pathfile and ProGlider files to create a glide path; their results showed less stress during root canal preparation in a group in which ProGlider files were used. In the abovementioned studies, it has been shown that increasing the angle of the ProGlider file toward the coronale, just as with the WaveOne Gold Glider that we used, reduced the stress between the file and canal walls that occurs during root canal preparation with shaping/finishing instruments.

The number of studies (17,23-26) evaluating torque and stress accumulation occurring during root canal preparation is limited. These studies have used different methods. One study (17) measured the stress occurring on the root surface, while others evaluated this stress using finite element analysis (17,25). On the other hand, there are studies measuring the torque accumulation during file motions using several tools. In these studies, the real time torque data of each endodontic motor were transferred to computer programs (15,26). In our study, data were created by transferring the voltage values that occurred during the canal preparation to a computer program. A total of 222.400 peak voltage values were recorded by acoustic test and evaluated during statistical analyses. This sample size is much larger than for previous studies that evaluated stress concentrations on root canal walls during preparation.

Sound signature monitoring of the moving parts of the devices or machinery and determining the condition of the related equipment by processing this data is referred to as acoustical analysis. In this study, acoustic data were obtained by piezoelectric sensors (27,28). Since the files and blocks used in the study are small in size, the piezoelectric sensor was chosen in accordance with those dimensions; the dimensional flexibility in the selection of the sensor has provided a great advantage. In addition, when the literature is examined, it can be seen that similar studies were conducted by the finite element method or by converting the electrical consumption of the device to torque. The difference in the acoustic analysis employed in this study is that instead of obtaining the stresses through the finite element model and analyzing the stress values at the end of the process, the maximum stress values are picked up as maximum peaks of the sound signal and the dynamic stress fluctuations are obtained as the amplitude change of the sound signal while the preparation is in progress. This method was chosen to obtain more data points for the acoustic analysis and to examine the change in mechanical stress value with a much wider data range. The main purpose here is to achieve more accurate results for the stress values. Studies (15,22) have shown that the canal volume before the root canal preparation process can influence the torque accumulation and stress that occur during the preparation. Since the root canal volumes of natural teeth vary, to obtain a standardization among the samples, artificial acrylic canals were used in the present study. However, it should be considered that a difference of stiffness in dentine and resin material can affect strain and stress occurring during the preparation.

CONCLUSION

Stress occurring in root canal reparation might be the primary cause of file fractures and dentinal crack formation. The result of the present study indicates that creating a glide path in the curved canals can reduce the stress occurring during root canal preparation.

Author Contribution Statement:
Concept - D.K., K.K., E.K.; Design – D.K., K.K., E.K.; Supervision – Collection and/or Processing – D.K., K.K., E.K.; Analysis and/ or Interpretation – D.K., K.K., E.K.; Literature Search – D.K., K.K., E.K.; Writing Manuscript – D.K., E.K.; Critical Review – D.K., E.K.

Informed Consent:
Written informed consent was obtained from participants who participated in this study.

Conflict of Interest:
The authors declare that they have no conflict of interest.

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