Original Article

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Cyclic Fatigue Resistance of Biorace Nickel-titanium File with Variable Taper after Immersion in Sodium Hypochloride

Sodyum Hipokloritin Farklı Taperlardaki Biorace Nikel Titanyum Eğesinin Döngüsel Yorgunluk Direncine Etkisinin Değerlendirilmesi

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ABSTRACT

Objective: This study aimed to evaluate the effect of sodium hypochlorite on the cyclic fatigue resistance of BioRace (BR) files according to taper.

Methods: BR 25.04 and 25.06 files were divided into the following groups: group 1, 20 BR 25.04 with no immersion in NaOCl; group 2, 20 BR 25.04 with immersion in 5.25% NaOCl at 37 °C ±1 °C for 5 min; group 3, 20 BR 25.06 with no immersion; and group 4, 20 BR 25.06 with immersion in 5.25% NaOCl at 37 °C ±1 °C for 5 min. The instruments were applied to a stainless-steel artificial root canal of 60° curvature and 5-mm radius. The time to failure (TTF) in seconds and number of cycles to failure (NCF) were recorded.

Results: The cyclic fatigue resistance of BR 25.04 was significantly higher than that of BR 25.06. The TTF and NCF values were significantly higher in group 1 than in groups 2 and 3 and in group 2 than in group 4. However, neither value differed significantly between groups 3 and 4 (p>0.05).

Conclusion: Taper and sodium hypochlorite affected the cyclic fatigue resistance of BR.

Keywords: BioRace, cyclic fatigue resistance, sodium hypochlorite, taper

ÖZ

Amaç: Bu çalışmanın amacı sodyum hipokloridin farklı taperlara sahip olan BioRace (BR) döner alet sisteminin döngüsel yorgunluğuna etkisini değerlendirmektir.

Yöntemler: BR 25,04 ve BR 25,06 enstrümanlarının döngüsel yorgunlukları, farklı koşullarda test edildi. Grup 1, BR 25,04 nolu eğe hiç bir solüsyonda bekletilmeden; grup 2: BR 25,04 %5,25 NaOCl solüsyonunda 37 °C ±1 °C'de 5 dakika bekletilerek; grup 3: BR 25,06 hiç bir solüsyonda bekletilmeden; grup 4: BR 25,06 %5,25 NaOCl solüsyonunda 37 °C ±1 °C'de 5 dakika bekletildikten sonra 60° kurvatür açılı and 5 mm kurvatür yarıçaplı paslanmaz çelik bloktan üretilmiş eğimli olukta test edildi. Her bir eğenin kırılana kadarki döngü sayısı (NCF) ve kırılana kadarki süresi (TTF) saniye cinsinden kaydedildi. Elde edilen veriler istatistiksel analizler ile değerlendirildi.

Bulgular: BR 25,04 eğesinin döngüsel yorgunluk direnci, BR 25,06'dan istatistiksel olarak daha yüksektir. TTF ve NCF değerleri grup 1 > grup 2 , grup 1 > grup 3 , grup 2 > grup 4 şeklinde bulundu. Buna karşılık, grup 3 ve grup 4 arasında istatistiksel olarak anlamlı bir fark yoktu.

Sonuç: Bu çalışmanın sınırları doğrultusunda BR ensturmanlarının taperı ve sodyum hipokloritte bekletilmesi aletin döngüsel yorgunluğuna etki etmektedir.

Anahtar Sözcükler: BioRace, döngüsel yorgunluk direnci, sodyum hipoklorit, taper

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Introduction

File failure during root canal instrumentation is challenging (1). Fracture of nickel-titanium (Ni-Ti) files can be caused by torsional stress or cyclic fatigue. Cyclic fatigue can occur when a file is exposed to repeated compression and tension (2,3). To reduce the frequency of fracture, new instruments manufactured from advanced alloys have been developed.

BioRace instruments (BR; FKG, La Chaux-de-Fonds, Switzerland) are manufactured from conventional austenite Ni-Ti and include six rotary instruments with electropolished surfaces, safety tips, triangular cross-sections with alternating cutting edges (4,5), and tapers of 0.02 to 0.08 (6).

Several factors influence the cyclic fatigue resistance of endodontic instruments, such as the manufacturing process, rotation type, operational speed, metal surface treatment, and immersion in disinfection solution (2-4,7). NaOCl solution is used for irrigation during endodontic procedures, and Ni-Ti instruments come into contact with this solution during root canal instrumentation and disinfection (8,9), which corrodes the instruments and does affect their cyclic fatigue resistance (2,10-12). However, contradictory results have been reported, which are likely due to differences in conditions (9-12).

To our knowledge, no study has investigated the effect of taper and NaOCl on the cyclic fatigue resistance of a file. Thus, this study aimed to evaluate the effect of NaOCl and taper on the cyclic fatigue resistance of BR Ni-Ti instruments. The null hypotheses were as follows:

1. The cyclic fatigue resistance of the file is not affected by its taper.

2. The cyclic fatigue resistance of the file is not affected by immersion in NaOCl solution.

Method

In this study, we tested the cyclic fatigue resistance of 40 BR 3 (25.04) and 40 BR 4 (25.06) Ni-Ti files in an artificial curved canal after immersion in NaOCl. The instruments were inspected under a surgical microscope (M320, Leica Microsystems, Wetzlar, Germany) at 20x magnification for defects and deformities. None of the instruments was discarded.

The files were randomly divided into the following groups (n=20 each): group 1, BR 3 with no immersion; group 2, BR 3 with immersion in 5.25% NaOCl at 37 °C ±1 °C for 5 min; group 3, BR 4 with no immersion; and group 4, BR 4 with immersion in 5.25% NaOCl at 37 °C ±1 °C for 5 min. The working part of the instrument was statically immersed in NaOCl and rinsed in 10 mL of distilled water. Then, the 16-mm working part of the instrument (curvature 60°, radius 5 mm) was applied to the stainless-steel artificial root canal (width 1.5 mm, depth 3.0 mm). The center of the curvature was 5 mm from the tip of the instrument, and the curved segment of the canal was 5 mm long. To reduce friction, synthetic oil was applied to the canal. The instruments were rotated freely inside the canal using an X Smart endodontic motor at 600 rpm and 1 N/cm until fracture occurred (Figure 1). To mimic physiological conditions, continuous irrigation with distilled water at 37 °C was performed.

Statistical Analysis

The time to failure (TTF; in seconds) was recorded both visually and audibly. The number of cycles to failure (NCF) was calculated by multiplying the time(s) to failure by the number of rotations or cycles per second, regardless of the direction of rotation (13). Data were subjected to the Shapiro-Wilk test to verify the assumption of normality. One-way analysis of variance and Tukey's multiple-comparison test were performed using NCSS™ 2007 software (NCSS, Kaysville, UT) with a significance level of 0.05. TTF and NCF values were subjected to Weibull reliability analysis to calculate the probability of survival.

Results

The mean NCF and TTF values are shown in Tables 1 and 2. The mean TTF of the BR 25.04 groups (groups 1 and 2) was greater than that of the BR 25.06 groups (groups 3 and 4). The resistance to cyclic fatigue of the BR instrument with a 0.06 taper was not significantly affected by immersion in NaOCl. However, static immersion in NaOCl for 5 min significantly reduced the cyclic fatigue resistance of the instrument with a 0.04 taper. The TTF and NCF values were significantly higher in group 1 than in groups 2 and 3 and in group 2 than in group 4. However, neither value differed significantly between groups 3 and 4 ($p>0.05$).

Weibull reliability plots with probability of survival values are shown in Figure 1, and the Weibull modulus, R^2, and number of cycles to 99% survival are presented in Table 2. The predicted TTFs for groups 1, 2, 3, and 4 were 43.24, 34.36, 25.38, and 26.62 s, respectively. The predicted number of cycles to 99% survival in groups 1, 2, 3, and 4 was 206.83, 186.68, 127.81, and 110.28, respectively.

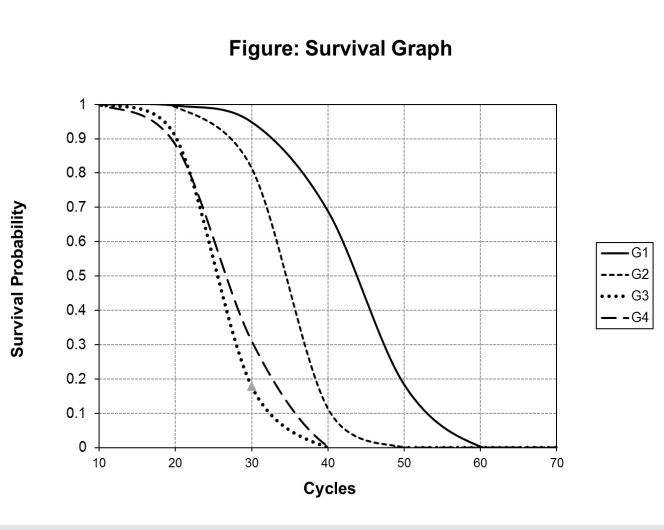

Figure 1. Probability of Survival Values of Groups (NCF, number of cycles to failure)
NCF: Number of cycles to failure

Discussion

We evaluated the effect of NaOCl on the cyclic fatigue resistance of a BR Ni-Ti instrument with different tapers. The null hypotheses that taper (BR) and immersion in NaOCl would not affect the cyclic fatigue resistance were rejected.

The cyclic fatigue resistance of a file decreases with increasing metal volume (14). In this study, files of one tip size but different tapers were tested to exclude the influence of other variables such as alloy type, cross section, and kinematics (7,15). Compared with BR 4 (0.06 taper), BR 3 (0.04 taper) had better cyclic fatigue resistance and NCF value regardless of immersion in NaOCl. This is in agreement with prior reports (16,17).

There is no universally accepted method for testing the cyclic fatigue resistance of endodontic instruments. Although the use of human teeth would be representative, it is impossible to standardize the tooth morphology (18). For this reason, artificial root canals are used to test cyclic fatigue resistance. Given the difficulty of shaping curved canals in the endodontic clinic, previous *in vitro* studies used 45°, 60°, 75°, and 90° curved canals of 5-mm radius (2,13,18). In this study, based on Pruett's method, a stainless-steel artificial root canal of 60° curvature and 5-mm radius was selected (19).

Endodontic instruments come into contact with NaOCl during root canal instrumentation and disinfection (12). Past studies of the effect of corrosion by NaOCl on the cyclic fatigue resistance of Ni-Ti instruments have yielded contradictory results (2,10). This could be caused by differences in the immersion time (1 min to 48 h), immersion type (static or dynamic), test protocol, instrument, heating (21 °C-60 °C), and concentration (9-12). Berutti et al. (10) evaluated the effect of hot NaOCl on a Protaper instrument using a 5-min contact time, and corrosion reduced its cyclic fatigue resistance. Saber et al. (18) investigated the effect of instrument material, taper, and degree of root canal curvature on the cyclic fatigue of the ProFile GT and Profile GT Series X. Instrument taper affected the cyclic fatigue resistance of both instruments. Topçuoğlu et al. (20) reported that immersion in 5% NaOCl for 5 min significantly decreased the cyclic fatigue resistance of several retreatment files with large metal volume. Elnaghy and Elsaka reported that the cyclic fatigue resistance of WaveOne Gold and Reciproc was considerably decreased by immersion in saline and NaOCl at 37 °C (2). However, Pedulla et al. (12) found that static or dynamic immersion in NaOCl for 1 or 5 min did not reduce the cyclic fatigue resistance of Ni-Ti instruments. Herein, we focused on the effects of taper and immersion time using a protocol based on that of Pedulla et al. (12). The 16-mm working part of the instrument was immersed in NaOCl at 37 °C ±1 °C to simulate *in vivo* conditions. In this way, galvanic corrosion phenomena caused by differences in the shape of the shaft and the working part of the instrument were eliminated (10). We used 5-min contact with NaOCl to simulate clinical practice (12).

Weibull analysis enables evaluation of the probability of instrument survival and prediction of the time and number of cycles to 99% survival. Higher Weibull modulus values indicate better reliability (21). BR 4 with immersion in NaOCl (group 4) had the lowest Weibull modulus and the fewest cycles (11.03) and shortest time (110.28 s) to 99% survival. BR 3 (no immersion) had the largest number of cycles to 99% survival (20.68) (Table 2).

Table 1. Comparison of time to fracture of groups with mean ± standard deviation (statistical level at p≤0.05)

	No immersion	Immersion in NaOCl	p value
	Mean ± SD	**Mean ± SD**	
25.04 BioRace (BR3)	Group 1: 43.24 (7.37)	Group 2: 34.35 (4.73)	0.001
25.06 BioRace (BR4)	Group 3: 25.88 (4.02)	Group 4: 26.62 (5.28)	0.668
p value	0.000	0.000	

SD: Standard deviation

Table 2. Sample size, NCF, Time to Fracture, Weibull Calculations Weibull calculations included Weibull modulus, coefficient of determination (R^2), and predicted cycles for %99 survival and time

	TTF (sec) Mean ± SD	NCF Mean ± SD	Weibull modulus	R2	Predicted cycles for % 99 survival	Predicted time (sec) for % 99 survival
G1	43.24	432.40	6.24	0.92	20.68	206.83
G2	34.36	343.60	7.54	0.90	18.67	186.68
G3	25.88	258.80	6.52	0.84	12.78	127.81
G4	26.62	266.20	5.22	0.94	11.03	110.28

SD: Standard deviation, NCF: Number of cycles to failure

Conclusion

Taper and NaOCl affected the cyclic fatigue resistance of BR files. As the taper of the BR file increased, the cyclic fatigue resistance decreased. In contrast, immersion in NaOCl decreased the cyclic fatigue resistance of BR instruments with a 0.04 taper but had no effect on those with a 0.06 taper.

Ethics

Ethics Committee Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent: For this type of study, formal consent is not required.

Peer-review: Externally peer reviewed.

Authorship Contributions

Surgical and Medical Practices: B.A.Ö., Concept: B.A.Ö., A.A.A., Design: B.A.Ö., A.A.A., Data Collection or Processing: A.A.A., Analysis or Interpretation: B.A.Ö., A.A.A., Literature Search: B.A.Ö., A.A.A., Writing: B.A.Ö.

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