Success and Failure of Nonsurgical Root Canal Treatment Performed by Dental Students: A Retrospective Study

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Abstract

The purposes of this study were to determine the success and failure rates of root canal treatment and determine factors affecting the success and failure of root canal treatment performed by undergraduate students at the Faculty of Dentistry, Naresuan University, Phitsanulok, Thailand, from May 2015 to April 2020.

Data of 176 anterior teeth and premolars from dental treatment records and radiographs were collected and evaluated. Digital periapical radiographs were evaluated by the Periapical index (PAI) score system. The treatment outcome was assessed based on the clinical and radiographic findings. Factors affecting the outcome were analyzed using the Chi-square test and logistic regression model.

The recall rate was 32.8%. The overall success rate was 84.1%, whereas the failure rate was 15.9%. The multivariate analysis identified that factors affecting outcome were the presence of pre-operative periapical lesion size < 5 mm (P=.025), periapical lesion size ≥ 5 mm (P=.005), and the occurrence of occlusal trauma (P=.040), with odds ratios of 0.18, 0.13, and 0.09, respectively.

The teeth without periapical lesions had a better success rate than those with lesions. The occlusal trauma is an important factor in prolonging periapical healing of root canal treated teeth.

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Introduction

Root canal treatment aims to eliminate bacteria within the root canal system by using mechanical instrumentation together with chemical irrigation and root canal filling with inert material. These procedures promote the recovery of the periapical tissue.[1]

Many studies reported the success and failure rates of root canal treatment. The systematic review showed the success of root canal treatment ranges from 31% to 96%.[2] The results of the studies varied depending on the different study characteristics and criteria for outcome assessment. Factors such as the presence of the preoperative periapical lesion, the quality of root canal filling, the apical extent of treatment, and the quality of coronal restoration may influence the outcome of the treatment.[1]

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In Thailand, few studies evaluated the success rate of root canal treatment performed by undergraduate students. They reported that the success rate ranges from 61% to 82%.[3-5] The presence of the preoperative periapical lesion[3], the apical extent of treatment[3], the occurrence of complications[3], the quality of root canal filling[5], the quality of the coronal restoration[3-5], and the recall period[5] were factors that influenced the success of root canal treatment. In addition, a previous study of Naresuan University evaluated the outcome of endodontic treatment performed by dental students from 2010 to 2015. This study showed that the overall success rate of endodontic treatment was 72.8%, and the failure rate was 27.2%. The factors that significantly influenced the outcome found in this study were the periapical status, and the recall period.[6]

According to our research, few studies have long-term evaluated the outcome of root canal treatment by dental students in Thailand. Thus, the purpose of this study was to determine the success and failure rates of root canal treatment and determine factors affecting the success and failure of root canal treatment

performed by undergraduate students at the Faculty of Dentistry, Naresuan University from May 2015 to April 2020.

Materials and methods

This retrospective study obtained ethical approval from the Human Research Ethics Committee of Naresuan University (No. P10047/64). This study obtained data from dental treatment records and radiographs of root canal treated teeth performed by undergraduate dental students at the Endodontic Clinic, Faculty of Dentistry, Naresuan University, Phitsanulok, Thailand, from May 2015 to April 2020.

All teeth were performed root canal treatment by undergraduate students under the supervision of experienced endodontists. All teeth were treated with an aseptic technique under rubber dam isolation. After access cavity preparation, the working length was established at 0.5 mm, using an electric apex locator and digital radiography. All root canals were mechanically prepared by stainless-steel K-files with the step-back technique until a master apical file size #30 or larger was obtained. Irrigation was frequently performed with 2.5% sodium hypochlorite (NaOCl). Calcium hydroxide applied with a lentulo-spiral was used as an interappointment dressing for teeth treated at least 2 weeks before canals were obturated. The interappointment temporary restorations were Cavit™ and IRM®. At the obturation appointment, the root canal was obturated when the tooth exhibited normal clinical signs and symptoms, absence of sinus tract, and dried and odorless dressing. Before obturation, root canal irrigation was performed with 2.5% NaOCl, 17% ethylene-diamine-tetraacetic acid (EDTA) solution, normal saline, and 2% chlorhexidine gluconate (CHX) accordingly. The canals were dried with paper points and obturated by lateral condensation technique with gutta-percha and either zinc oxide eugenol-based root canal sealer or epoxy resin-based root canal sealer (AH Plus®). After root canal treatment, the treated teeth were intermediately restored with Cavit™ and composite resins await the permanent restorations. Finally, the teeth were either permanent restorations with direct composite fillings or indirect restorations with post and core crowns.

After treatment completion of at least 6 months, the students who were assigned for the recall as the regular program requirement. The patients were reexamined by undergraduate students who were not the treatment operators. Patient information and treatment records were normally recorded in the dental charts of each patient at the time of treatment by the operator. The following factors were obtained from dental charts: age, gender, tooth location, tooth type, pulp status, the occurrence of procedural complications, breaking of interim restorations, the recall period, types of restoration, the quality of coronal restoration, abutment for prosthesis, duration before the final restoration and the occurrence of occlusal trauma. The cases with procedural errors were included in this study. The types of procedural errors such as perforation, separated instruments, or root canal transportation were also recorded. The perforation defect was repaired with either glass ionomer cement (GIC) or mineral trioxide aggregated (MTA) under the dental operating microscope by the experienced endodontist.

The other factors were obtained from digital periapical radiographs: periapical status, size of the periapical lesion, and the apical extent of root canal filling. Before radiographic interpretation, three independent examiners were calibrated for periapical index (PAI) score. The intra-examiner and inter-examiner reliability were evaluated using Cohen kappa statistics. The pre-operative and follow-up periapical status were defined by the PAI score system independently by two examiners. In case of disagreement, the final evaluation was decided by a third examiner.

The treatment outcome was dichotomized as “success”, with a PAI ≤ 2 and no clinical signs or symptoms, or “failure”, with a PAI ≥ 3, or presence of clinical signs or symptoms, or post-treatment endodontic intervention or extraction for endodontic disease. Furthermore, the treatment outcome was evaluated as “functional”, with an absence of clinical signs or symptoms regardless of the PAI score.

All data were processed and analyzed via IBM SPSS Statistics Version 26. The univariate describes the data using percentage frequencies. The bivariate associations were tested between the treatment outcomes and factors by using a Chi-square test. The multivariate associations were tested for evaluating associations between various factors by using logistic regression. All statistical tests were performed as two-tailed and

interpreted at a 5% significance level.

Results

According to radiographic interpretation, the Kappa scores of the inter-examiner agreement of examiners 1 and 2, 1 and 3, 2 and 3 were k = 0.875, 0.810, and 0.745 respectively. The Kappa scores of the intra-examiner agreement of the three examiners were k = 0.812, 0.874, and 1.000 respectively. These Kappa scores indicated excellent agreement.

Of the 555 treated teeth, 373 teeth were excluded as patients declined to recall. Of the responding 182 samples, 6 teeth were excluded: 2 teeth having an incomplete set of digital periapical radiographs, and 4 teeth not being initial root canal treated teeth. A total of 176 teeth were subjected to statistical analysis as shown in Table 1. The recall rate in this study was 32.79%.

In this study, the mean age of the patients was 31.95 years, ranging from 14 to 77. The mean of the recall periods was 17.67 months, ranging from 6 to 60 months. Based on the data of this study, the overall success rate was 84.1% (148 teeth), whereas the failure rate was 15.9% (28 teeth). There were 171 teeth with an absence of clinical signs or symptoms regardless of the PAI score, therefore the functional rate of treated teeth was 97.2%.

According to the bivariate analysis, factors significantly affecting treatment outcome of initial root canal treatment were tooth type (P=.006), pulp status (P=.006), pre-operative periapical status (P=.000), and the occurrence of occlusal trauma (P=.020) as presented in Table 1. Anterior teeth had a success rate of 78.2% (86 from 110 teeth) and premolars had a success rate of 93.9% (62 from 66 teeth). The success rates according to the pulp status were 94.8% (55 from 58 teeth) of teeth with vital pulp and 78.8% (93 from 118 teeth) of teeth with non-vital pulp. As reported by pre-operative periapical status, the success rates of teeth with the absence of periapical lesion, with periapical lesion size < 5 mm, and with periapical lesion size ≥ 5 mm. were 94.6% (87 from 92 teeth), 77.1% (27 from 35 teeth), and 69.4%, (34 from 49 teeth), respectively. The success rates based on the occurrence of occlusal trauma were 85.3% (145 from 170 teeth) with the absence of occlusal trauma and 50.0% (3 from 6 teeth) with the presence of occlusal trauma. Factors not affecting treatment outcome of initial root canal treatment were age (P=.906), gender (P=.224), tooth location (P=.462), the presence of complications (P=.440), breaking of interim restorations (P=.350), the apical extent of root filling (P=.716), recall period (P=.686), types of restoration (P=.137), quality of restoration (P=.599), abutment of prosthesis (P=.136), and duration of final restoration (P=.641) as presented in Table 1.

To eliminate the confounding factors that might have affected these results, multiple logistic regression was used. The particular factors and magnitude of their effects on success, presented by adjusted odds ratios (OR), are also presented in Table 2. The logistic regression analysis revealed only 2 factors that statistically affected the outcome of treatment, which were the presence of pre-operative periapical status and the occurrence of occlusal trauma. Based on pre-operative periapical status, the odds ratios were 0.18 and 0.13 for the presence of pre-operative periapical lesion sizes < 5 mm and ≥ 5 mm, respectively. The occurrence of occlusal trauma had an odds ratio of 0.09. The probability of success in teeth with pre-operative periapical lesion size < 5 mm was 0.18 that of teeth with no lesion (P=.025), and in teeth with pre-operative periapical lesion size ≥ 5 mm was 0.13 that of teeth with no lesion (P=.005). The probability of success of teeth with the presence of occlusal trauma was 0.09 that of teeth with the absence of occlusal trauma (P=.040).

Discussion

In this study, we controlled this factor by calibrating the three examiners before the beginning of the study. The Kappa statistics showed that the mean of the inter-observer agreement was 0.81, which indicated excellent agreement, to reduce the disagreement between the examiners.

The recall rate in this study was 32.79%, which is consistent with previous studies in Thai dental schools, including a study from Naresuan University in 2010-2015, ranging from 21 to 41%.[3-6] However, other studies also reported a wide range of recall rates from 12% to 100%.[10-12] A large proportion of patients in the dental school of Naresuan University are students who may relocate after graduation, resulting in a low recall rate. In addition, many dropouts were either

unavailable, unresponsive to recall, and/or did not have any signs or symptoms that had no motivation to attend.

The clinical signs and symptoms including pain, swelling, presence of a sinus tract, loss of function, and evidence of tissue destruction were evaluated.[13] The radiographic evaluation of this study was based on the PAI score system.[7] The system is reasonably accurate, repeatable, and can distinguish between sub-populations. It also allows comparing results from different investigations. According to these outcome criteria, 148 teeth (84.1%) were classified as a success, and 28 teeth (15.9%) as a failure. Furthermore, 171 teeth (97.2%) were classified as functional. These results were in agreement with the systematic review of clinical studies that reported 74 to 86% success rates, and 91 to 97% functional rates.[8]

The success rate in this study was higher than the previous study of Naresuan University[6], in which the success rate was 72.8%. Whereas the functional rate was similar to the results reported earlier (96.2%). These results can be explained by the higher proportion of teeth with pre-operative periapical lesions in the previous study (62.4% vs 47.7%). The presence or absence of pre-operative periapical lesion significantly influences the success rate of root canal treatment.[9] In addition, the treatment protocol of final rinsing in this study was changed from the previous study. The final rinsing protocol of the current study was 2% CHX, while 2.5% NaOCl was used as the final rinse in the previous study. The study by Zamany *et al*. [10] has suggested that the addition of 2% CHX was significantly more effective than the conventional protocol in providing a bacteria-free root canal. CHX is a broad-spectrum cationic antiseptic with a bisbiguanide base and has been shown a substantivity to the dental structure which has the unique ability of hydroxyapatite binding.[11] Moreover, CHX is particularly efficient against *Enterococcus faecalis*, a microorganism involved in treatment failures.[12] However, the systematic review and meta-analysis [13] concluded that there was no difference in the antimicrobial efficacy of CHX and NaOCl.

In bivariate analysis, the four factors significantly affecting treatment outcome were tooth type, pulp status, pre-operative periapical status, and the occurrence of occlusal trauma. According to tooth type, there was a statistically significant difference in success rate (*P*=.006) that the outcome was better in premolars (93.9%) than anterior teeth (78.2%). However, the multivariate analysis did not identify any significant predictor of success. By contrast, Engström *et al*.[14] reported that single-rooted teeth showed a better prognosis than multi-rooted teeth, and the previous study[6] found that there was no statistically significant difference in success rate between premolars (79.4%) and anterior teeth (69.7%). This could be because in this study anterior teeth (57%) had more pre-operative periapical lesions than premolars (32%), whereas in the previous study, pre-operative periapical lesions in anterior teeth (79%) were not different from those in premolars (62%).

In teeth with vital pulp, the success rate was significantly higher than those with nonvital pulp (*P*=.006). The results of this study correspond with the meta-analysis reported by Kojima *et al*.[15] In necrotic teeth, there are more infections and a higher risk of bacteria remaining after endodontic treatment, which can cause persistent periapical inflammation.[16] However, this relationship is not significant when using multivariate analysis.

According to pre-operative periapical status, 92 teeth (52.3%) without periapical lesion, and 84 teeth (47.7%) with periapical lesion revealed a success rate of 94.6% and 72.6% respectively. Similarly, most studies concluded that the presence or absence of pre-operative periapical lesion significantly affects the rate of success of endodontic treatment. Teeth without periapical lesions had a better success rate than those with a lesion.[1, 17, 18] In addition, the multivariate analysis in this study also confirmed the presence of pre-operative periapical lesion as the predictor of outcome in initial root canal treatment.

The size of periapical lesions affected the treatment outcomes in this study, which corresponded with previous studies.[19, 20] The success rate of 77.1% for teeth with periapical lesion size < 5 mm was significantly higher than those with periapical lesion size ≥ 5 mm (69.4%). In consistent with multivariate analysis, which also identified that the presence of pre-operative periapical lesion size < 5 mm and periapical lesion size ≥ 5 mm significantly influenced the outcome of treatment, with odds ratios of 0.18

and 0.13 respectively. These results can be explained by the relationship between the size of the lesion and the number of microbes in the root canal. The root canals of teeth with lesions larger than 5 mm contained significantly more bacterial cells than teeth with smaller lesions.[21] Moreover, larger lesions required a longer healing time than smaller lesions.[22, 23]

Another factor affecting the treatment outcomes in this study was the occurrence of occlusal trauma. The success rate of 50.0% in teeth with occlusal trauma, was significantly lower than that in teeth without occlusal trauma (85.3%). Moreover, the multivariate analysis also identified that the occurrence of occlusal trauma significantly influenced the outcome of root canal treatment, with an odds ratio of 0.09. The effect of occlusal trauma on the pulp and periapical apparatus, or specifically on the outcome of root canal treatment, has been rarely studied. However, Matsumoto *et al*.[24] have suggested that occlusal trauma is a key factor in prolonging periapical healing of endodontically treated teeth. In contrast, ElDeeb & Andreasen[25] found that hyper- and hypo-occlusion did not affect the healing of the periodontal tissue in rats.

The procedural complication is also an important factor influencing the outcome of treatment. Contrary to other studies[26, 27], this study could not show a relationship between the presence of complications and treatment outcome. With the small number of teeth with procedural complications (10.8%), the success rate of teeth with complications was 77.8% (14 from 18 teeth), and the failure rate was 22.2% (4 from 18 teeth; 1 coronal root perforation, 1 ledge, and 2 apical transportations). In this study, root canals of teeth with ledge and transportation were filled with gutta-percha, and teeth with coronal perforation were repaired with GIC immediately or within 1 week after perforation. Moreover, root canals of teeth with apical perforations were filled with either gutta-percha or MTA within 3 months after perforation occurred. The prognosis of perforation depends on the location, size of the perforations, time of repair[28], and repair materials.[27] Several studies demonstrated that the biocompatibility and the sealing ability of GIC[29, 30] and MTA[29, 31] were effective in repairing root perforations. Therefore, the positive treatment outcome in teeth with perforations in this study was attributed to both GIC[32] or MTA[31] properties.

The effect of interim restorations on the success rate of root canal treatment has not been discussed in any previous studies. However, there is a possible decrease in favorable long-term treatment outcomes if the interim or temporary restorations break down at any time during the endodontic treatment process.[33] In this study. the teeth with the breaking of interim restorations were found in only 4.0% of subjects, therefore, there was no correlation between the breaking of interim restorations and treatment outcome.

The apical extent of root canal fillings was found to influence the prognosis of the treatment in some studies[14, 19] but did not influence prognosis in this study and others.[20, 21, 34] All treated teeth in this study followed the treatment protocol using electric apex locators and digital radiographs, allowing the apical extent of root canal filling to be controlled. Therefore, a small sample size of teeth with long root canal filling (n=10), and no teeth with short root canal filling were found.

Regarding the recall period, the previous studies[5, 6] showed that the different recall periods influenced treatment outcomes. On the contrary, there was no statistically significant difference in success rate between the different recall periods in this study. At least 1-year follow-up period is suggested for observing meaningful changes in periapical lesions, and the extension of the follow-up period (3-4 years) is required for a stable record of treatment outcome.[23-25]

Types of restoration were not significantly associated with treatment outcomes in this study, which was similar to the previous studies.[34, 35] In contrast, a systematic review[18] revealed that teeth restored with a permanent restoration or crown were associated with significantly higher survival than direct restorations. As stated by the duration of final restoration after root canal treatment, there was no statistically significant difference in success rate between the different durations. In contrast, Ahmad and Sadaf[36] showed a very significant correlation in the extraction of root canal treated teeth with a delay of more than 60 days of placement of final coronal restoration after completion of root canal treatment. The double layers of Cavit™ and composite resins were used as intermediate restorations in the treatment protocol of the current study, which provided an appropriate seal and strength, so the types of restoration and the

duration of final restoration may not affect the outcome of this study.

Quality of coronal restoration was one of the factors that was also examined. This study and other study[37] were unable to show a correlation between the quality of coronal restoration and treatment outcome. Conversely, some studies reported that satisfactory restorations were associated with significantly higher success rates than unsatisfactory restorations.[38, 39]

According to the use of teeth as the abutment of the prosthesis, some studies[23, 24] reported that bridge and denture abutments had significantly lower success rates than individual units. Most of the endodontically treated teeth in this study were not assigned as prosthesis abutments, therefore there was no effect on the treatment outcome. The meta-analysis by Ng *et al.*[18] reported that the teeth not functioning as fixed or removable prosthesis abutments were related to a significantly higher chance of survival than those that functioned as fixed prosthesis abutments.

Conclusions

Within the limits of retrospective study, this study focused on the fact that the teeth without periapical lesions had a better success rate than those with lesions. The occlusal trauma is a significant factor in prolonging periapical healing of root canal treated teeth.

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Declaration of Interest

The authors report no conflict of interest.

Factors		Total		Success		
		n	%	n	%	p-value
Pre-operative						
Age	< 60	156	88.6	131	84.0	0.906
	≥ 60	20	11.4	17	85.0	
Gender	Male	58	33.0	46	79.3	0.224
	Female	118	67.0	102	86.4	
Tooth location	Maxilla	142	80.7	118	83.1	0.462
	Mandible	34	19.3	30	88.2	
Tooth type	Anterior	110	62.5	86	78.2	0.006*
	Premolar	66	37.5	62	93.9	
Pulp status	Vital	58	33.0	55	94.8	0.006*
	Nonvital	118	67.0	93	78.8	
Periapical status	No lesion	92	52.3	87	94.6	0.000*
	< 5 mm	35	19.9	27	77.1	
	≥ 5 mm	49	27.8	34	69.4	
Intra-operative						
Occurrence of procedural complications	Absence	158	89.8	134	84.8	0.440
	Presence	18	10.2	14	77.8	
Breaking of interim restorations	Absence	169	96.0	143	84.6	0.350
	Presence	7	4.0	5	71.4	
The apical extent of root canal filling	Adequate	166	94.3	140	84.3	0.716
	Short	0	0	0	0	
	Long	10	5.7	8	80.0	
Post-operative						
Recall period	6-11 months	65	36.9	53	81.5	0.686
	12-23 months	68	38.6	59	86.8	
	24-35 months	27	15.3	24	88.9	
	36-47 months	11	6.3	8	72.7	
	≥ 48 months	5	2.8	4	80.0	
Types of restoration	Final	104	59.1	91	87.5	0.137
	Intermediate	72	40.9	57	79.2	
Quality of coronal restoration	Satisfactory	166	94.3	139	83.7	0.599
	Unsatisfactory	10	5.7	9	90.0	
Abutment for prosthesis	No	165	93.8	137	83.0	0.136
	Yes	11	6.3	11	100.0	
Duration of final restoration	< 2 months	36	34.6	30	83.3	0.641
	2-6 months	21	20.2	19	90.5	
	> 6 months	47	45.2	42	89.4	
Occurrence of occlusal trauma	Absence	170	96.6	145	85.3	0.020*
	Presence	6	3.4	3	50.0	
Clinical findings	Absence	171	97.2			
	Presence	3	1.7			
	Extracted	2	1.1			

Table 1. Frequency distribution of data and successful outcome by tooth.
* Indicates a statistical significance (p<.05).

Factors (n)	Success (N=148)		Failure (N=28)		Cruded OR [95% CI]	p-value of cruded OR	Adjusted OR [95% CI]	p-value of adjusted OR
	n	%	n	%				
Tooth type								
Anterior (110)	86	58.1	24	85.7	ref		ref	
Premolar (66)	62	41.9	4	14.3	4.33 [1.43-13.10]	0.006*	3.21 [0.85-12.13]	0.086
Pulp status								
Vital (58)	55	37.2	3	10.7	ref		ref	
Nonvital (118)	93	62.8	25	89.3	0.20 [0.06-0.70]	0.006*	0.75 [0.16-3.60]	0.721
Periapical status								
No lesion (92)	87	58.8	5	17.9	ref		ref	
< 5 mm (35)	27	18.2	8	28.6	0.19 [0.06-0.64]	0.209	0.18 [0.04-0.81]	0.025*
≥ 5 mm (49)	34	23.0	15	53.6	0.13 [0.04-0.39]	0.001*	0.13 [0.03-0.54]	0.005*
Complications								
Absence (158)	134	90.5	24	85.7	ref		ref	
Presence (18)	14	9.5	4	14.3	0.63 [0.19-2.07]	0.440	0.47 [0.10-2.09]	0.319
Breaking of interim restorations								
Absence (169)	143	96.6	26	92.9	ref		ref	
Presence (7)	5	3.4	2	7.1	0.46 [0.08-2.47]	0.350	0.23 [0.03-1.76]	0.157
The apical extent of root canal filling								
Adequate (166)	140	94.6	26	92.9	ref		ref	
Long (10)	8	5.4	2	7.1	0.74 [0.15-3.70]	0.716	0.61 [0.07-5.47]	0.654
Recall period								
6-11 months (65)	53	35.8	12	42.9	ref		ref	
12-23 months (68)	59	39.9	9	32.1	1.48 [0.58-3.80]	0.442	1.08 [0.36-3.26]	0.887
24-35 months (27)	24	16.2	3	10.7	1.81 [0.47-7.02]	0.459	1.21 [0.19-7.57]	0.836
36-47 months (11)	8	5.4	3	10.7	0.60 [0.14-2.62]	0.287	0.43 [0.07-2.61]	0.362
≥ 48 months (5)	4	2.7	1	3.6	0.91 [0.09-8.85]	0.800	0.55 [0.04-7.04]	0.644
Types of restoration								
Final (104)	91	61.5	13	46.4	ref		ref	
Intermediate (72)	57	38.5	15	53.6	0.54 [0.24-1.22]	0.137	0.58 [0.19-1.75]	0.336
Quality of restoration								
Satisfactory (166)	139	93.9	27	96.4	ref		ref	
Unsatisfactory (10)	9	6.1	1	3.6	1.75 [0.21-14.37]	0.599	1.36 [0.12-15.22]	0.801
Occurrence of occlusal trauma								
Absence (170)	145	98.0	25	89.3	ref		ref	
Presence (6)	3	2.0	3	10.7	0.17 [0.03-0.90]	0.020*	0.09 [0.01-0.89]	0.040*

Table 2. The results of multivariate analysis of the particular factors affecting the treatment outcome (N=176).

*Indicates a statistical significance (p<.05), OR = Odds ratio. CI = Confidence interval.

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