

Original Article

Impact of anatomical and clinical variables on the success of endodontic instrument fragment retrieval

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Received July 14, 2024; Revised September 18, 2024; Accepted September 20, 2024; J-STAGE Advance Publication: November 22, 2024

Abstract

Purpose: Separation of instrument fragments can impede the progress of endodontic treatment, and effective management of this complication is crucial for treatment success. This study examined the factors that impact the success of retrieval of separated instrument fragments by postgraduate endodontic residents.

Methods: A retrospective analysis was conducted on a total of 224 teeth associated with instrument fragment separation that were managed by postgraduate residents specializing in endodontics between January 2020 and March 2024. Data were extracted from patient records, periapical radiographs, and clinical notes. Chi-squared test and *t*-test were employed to identify factors significantly influencing retrieval success. Associations between successful retrieval and variables were assessed using binary logistic regression models.

Results: Fragment retrieval was successful in 32% of the examined cases. Retrieval was more likely to be successful for anterior teeth than for premolars and molars ($P = 0.003$). Fragment separation in the coronal third of the canal had a higher retrieval success rate ($P < 0.001$). Longer separated fragments were also associated with increased retrieval success ($t = 3.035$, $P = 0.003$).

Conclusion: The study revealed that factors critically influencing the successful retrieval of separated instrument fragments included the tooth type, the level of separation within the canal, and the fragment length. These findings highlight the importance of careful case selection in order to optimize management outcomes.

Keywords: instrument fragment removal, retrospective study, separated instrument fragments, ultrasonics

Introduction

Separation of instrument fragments can impede the progress of endodontic treatment, potentially compromising the success of the procedure and leading to adverse clinical outcomes [1,2]. Effective management of fragment separation is crucial for successful endodontic treatment. The incidence of separated instrument fragments within root canals has been documented in several studies [3-5]. Spili et al. reported an overall prevalence of 3.3% [3], whereas other studies observed incidences ranging from 1.0% to 2.2%, notably in molar teeth and curved canals [6]. Another study of single-file reciprocating systems noted a fracture rate of 0.9% out of 2,056 cases [7]. Overall, the prevalence of instrument separation ranges from 0.4% to 10%, and is influenced by factors such as the type of instrument, tooth anatomy, and clinician expertise [3,8,9].

The success rates for fragment retrieval vary widely, with a reported range of 53% to 95% [8-10]. One study reported an overall success rate of 53% for retrieving or bypassing fragments [9], whereas another study, utilizing a dental operating microscope and ultrasonic tips managed by a

single endodontist, achieved a 95% success rate for removal of separated instrument fragments from consecutive referral cases [11]. Retrieval success is closely linked to anatomical factors such as root curvature, length, and tooth type [5,8,9,11]. Curved canals, especially those of molars, have lower retrieval success rates, whereas longer fragments are generally easier to retrieve [9]. Use of a dental operating microscope significantly enhances visualization and control, thereby contributing to higher success rates [12,13]. Visibility within the root canal also significantly influences retrieval success, which is more likely for visible than for non-visible fragments [12]. Fragment location within the root canal also plays a crucial role in retrieval success, being more likely for the coronal and middle thirds than for the apical third [5,8,14]. However, prolonged treatment may negatively impact success rates [8,14].

Under favorable conditions, retrieval of a retained instrument fragment can be a conservative procedure [15]. However, difficulties with access and limited visibility can lead to iatrogenic complications during retrieval attempts, such as ledge formation, perforation, or excessive canal enlargement, resulting in a weakened root structure prone to vertical fracture [8,14,16-19]. Furthermore, the retrieval process may lead to additional complications, including fracture of a second instrument or extrusion of the separated fragment [20]. Therefore, careful consideration is essential when deciding whether to proceed with fragment retrieval.

Given the complexities and challenges associated with the management of instrument separation during endodontic treatment, the present study aimed to examine the factors that impact the successful retrieval of separated fragments by postgraduate (PG) endodontic residents. By identifying these factors, the study sought to provide insights that would be useful in clinical practice and enhance endodontic treatment outcomes.

Materials and Methods

Patient inclusion criteria

Ethical approval for this study was obtained from the Institutional Research Board and Research Ethics Committee at King Abdulaziz University Dental Hospital (KAUDH) (ethical clearance number 4568799). A retrospective analysis was conducted on cases managed by PG endodontic residents at KAUDH between January 2020 and March 2024, when management of instrument separation was performed.

Data collection and preoperative measurements

Data were extracted from patient records, periapical radiographs, and clinical notes, using the R4 software Carestream DENTAL R4 Clinical system version 5.5.0 (Carestream Dental, Atlanta, GA, USA). Comprehensive information, including demographics, clinical history, and type of management, was collected for each case, and personal identifiers were removed to ensure patient confidentiality. Data collection was facilitated using Microsoft Excel version 16.66.1 (Microsoft Corp., Redmond, WA, USA).

Preoperative radiographs were used to collect details about the type and root of the tooth, including the degree of root canal curvature, the location of the fragment, and the radiographic length of the fragment. The method described by Schneider [21] was used to determine canal curvature, which was classified as straight ($\leq 5^\circ$), moderate (6° to 20°), or severe ($> 20^\circ$). An illustration of Schneider's method is shown in Fig. 1. Instrument separation length was measured in millimeters from periapical radiographs. The location of the separated fragment within the root canal was identified as the coronal third, middle third, or apical third. The position of the fragment

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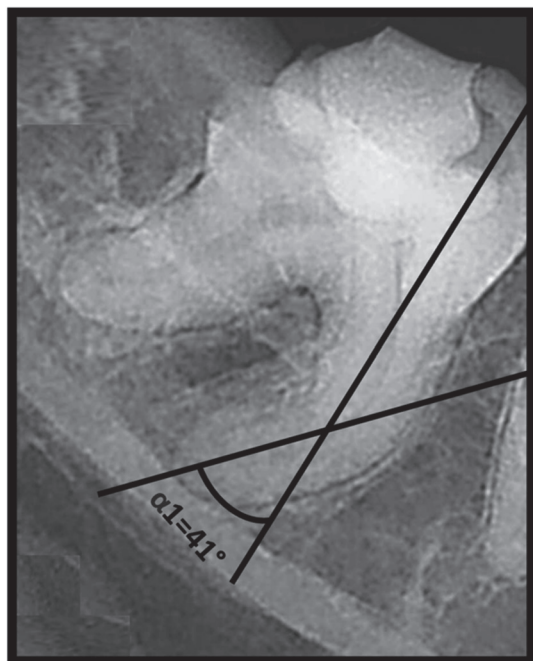


Fig. 1 The degree of root canal curvature was assessed using Schneider's method, which involves measuring the angle between the straight line representing the canal's long axis and the actual curved path of the canal. This angle quantifies the extent of canal curvature. In the figure, the molar tooth displays a curvature angle of 41 degrees, indicating severe canal curvature.

relative to the curvature of the root canal was also determined as coronal or apical to the curvature. Radiographic interpretation was independently performed by two dentists under standardized viewing conditions. Their observations were compared, and in cases of disagreement, the two examiners reassessed the radiographs together to reach a consensus.

Retrieval of separated instrument fragments

For the retrieval of instrument fragments, residents followed specific protocols. Initially, straight-line access to the coronal portion of fragment was attempted. Gates-Glidden burs (Dentsply Maillefer, Ballaigues, Switzerland) were used to prepare a platform at the coronal end of the fragment. Then, an ultrasonic tip was applied in a counterclockwise direction to remove dentin and to trephine around the fragment. Subsequently, the separated fragment was ultrasonically vibrated and flushed out of the root canal. If this method was unsuccessful, an attempt was made to remove the fragment using the braiding technique with Hedström files. The first Hedström file was gently screwed into the canal alongside the fragment, followed by the introduction of two additional Hedström files. These files were then wound around one another and withdrawn together. In most cases, multiple techniques were employed until either the retrieval was successful, or the attempt was terminated. All procedures were conducted by PG residents under the supervision of endodontic consultants.

Statistical analysis

Prior to study commencement, statistical power calculations were performed using G*Power (version 3.1; Heinrich Heine University Düsseldorf, Düsseldorf, Germany). This analysis determined that a minimum sample size of 132 independent teeth would be required to achieve 80% statistical power at a significance level of 0.05, accounting for anticipated differences in management strategies based on existing literature and record reviews. Cases were stratified into two groups based on the retrieval outcome: success and failure. Failure was defined as instances where the fragment was not retrieved, only bypassed, left in situ without bypassing, or when procedural errors occurred during the retrieval attempt.

Descriptive statistics were computed to summarize the characteristics of the dataset. Mean and standard deviation were calculated for continuous variables, while counts and percentages were used for categorical variables. Statistical analyses involved the use of the chi-squared test of independence or Fisher's Exact test to assess the significance of preop-

erative factors and successful retrieval. Associations between successful retrieval and variables (type of tooth, and level of separation) were assessed using multiple binary logistic regression models. Non-adjusted odds ratio (OR) and 95% confidence intervals (CI) were obtained.

Furthermore, a *t*-test for independent samples was employed to assess whether there was a significant difference in the length of the instrument fragment between the successful retrieval group and the failure group. Binary logistic regression analysis was conducted to investigate the association between the length of the fragment and the likelihood of successful retrieval. All statistical analyses were two-sided, with a significance threshold set at 0.05, and performed using SPSS Statistics software version 28 (IBM Corp., 2021, Armonk, NY, USA).

Results

In this study, 300 cases were initially reviewed, among which PG residents attempted to retrieve separated instrument fragments from 224 teeth, with outcomes that were either successful or unsuccessful.

Cases lacking radiographic evidence, or those with incomplete records or insufficiently detailed notes, were excluded. The average age of the patients included in the analysis was 33.4 years (± 11.3). Factors shown to significantly influence successful retrieval included tooth type, the level of instrument fragmentation, and the length of the separated fragment (Tables 1 and 2).

Anterior teeth exhibited a substantially higher probability of successful instrument retrieval compared to premolars and molars, as determined by chi-squared analysis ($P = 0.003$), with a risk ratio of 2.143 (CI: 1.37-3.33), indicating that the probability of successful retrieval was more than twice as high for anterior teeth. Specifically, within the subset of anterior teeth, 64% of separated fragments were successfully retrieved (Table 1). Multiple regression analysis showed that the odds ratio for retrieval success in anterior teeth was 4.2 times higher than that for premolars and molars (OR = 4.2, CI: 1.3-13.03, $P = 0.013$), as shown in Table 3.

Additionally, the location of the instrument fragment within the root canal system emerged as a significant factor determining retrieval success. Retrieval was successful in almost 90% of all instances of instrument fragmentation occurring at the coronal level. However, retrieval rates decreased significantly for separations in the middle and apical thirds (chi-squared, $P < 0.001$), as shown in Table 1. The risk ratio for successful retrieval was 2.99 (95% CI: 2.19-4.06) for separations at the coronal level compared to those in the middle and apical thirds, indicating that separations at the coronal level had nearly three times the odds of successful retrieval. Results of multiple binary regression showed that the likelihood of successful retrieval of a separated fragment in the coronal third was 18.8 times greater than for the middle or apical third (OR = 18.87, CI: 2.3-54.03, $P = 0.006$), as shown in Table 3.

The *t*-test for independent samples showed a significant mean difference in the length of separated fragments between the successful and unsuccessful groups ($t = 3.035$, $P = 0.003$), as shown in Table 2. Specifically, the mean length of retrieved separated fragments was 5.2 mm (± 0.62), being longer than the mean length of unsuccessfully retrieved fragments, which was 1.9 mm (± 0.16). Logistic regression analysis revealed that longer separated fragments were associated with an increased likelihood of retrieval success, with an odds ratio of 1.183 (OR = 1.183, 95% CI = 1.07-1.3, $P = 0.001$), as shown in Table 3. This indicated that for every one-unit increase in length, there was an increase in the odds of successful retrieval by 18.3%.

Tables 1 and 2 provide detailed information regarding all of the studied factors.

Discussion

Instrument separation during endodontic procedures poses a significant challenge to clinicians, often necessitating careful decision-making to ensure successful treatment outcomes [2]. The present retrospective analysis aimed to explore the factors influencing the successful retrieval of separated instrument fragments in cases managed by PG endodontic residents, thus aiding decision-making for management of this complication and enhancing clinical practice and treatment efficacy. The results revealed several factors that significantly influenced retrieval success, including the

Table 1 Analysis of success and failure rates for instrument retrieval across various factors using the chi-squared test ($n = 224$)

Variable	Success n (%)	Failure n (%)	No. of teeth	P -value
Gender				
female	40 (31.7)	86 (68.3)	126	0.885
male	32 (32.7)	66 (67.3)	98	
Tooth type				
anterior	9 (64.3)	5 (35.7)	14	0.003
premolar	4 (13.3)	26 (86.7)	30	
molar	59 (32.8)	121 (67.2)	180	
Pulpal diagnosis				
irreversible pulpitis	10 (40.0)	15 (60.0)	25	0.663
pulp necrosis	3 (30)	7 (70)	10	
previously initiated	25 (35.2)	46 (64.8)	71	
previously treated	34 (28.8)	84 (71.2)	118	
Apical diagnosis				
normal apical tissue	11 (28.2)	28 (71.8)	39	0.184
symptomatic apical periodontitis	37 (29.4)	89 (70.6)	126	
asymptomatic apical periodontitis	18 (36.0)	32 (64.0)	50	
acute apical abscess	3 (60.0)	2 (40.0)	5	
chronic apical abscess	3 (75.0)	1 (25.0)	4	
Crown condition				
restoration/caries	65 (32.3)	136 (67.7)	201	0.951
restored with a crown	7 (30.4)	16 (69.6)	23	
Special canal anatomy				
calcified/blocked canals	8 (47.1)	9 (52.9)	17	0.365
curved canal	12 (34.3)	13 (65.7)	25	
narrowed canal	52 (30.2)	120 (69.8)	172	
Number of separated instrument fragments per tooth				
one	63 (31.5)	137 (68.5)	200	0.552
more than one	9 (37.5)	15 (62.5)	24	
Presence of periapical lesion				
present	33 (35.1)	61 (64.9)	94	0.419
absent	39 (30.0)	91 (70.0)	130	
Number of visits				
one visit	65 (32.2)	137 (67.8)	202	0.973
two visits	7 (31.8)	15 (68.2)	22	
Separated by				
dental student/Intern	12 (36.4)	21 (63.6)	33	0.955
endodontic resident	41 (30.0)	96 (70.0)	137	
general dentist	15 (33.3)	30 (66.6)	45	
unknown	4 (44.4)	5 (55.5)	9	
Root curvature				
mild (<5 degrees)	56 (31.6)	121 (68.4)	177	0.931
moderate (5-25 degrees)	16 (37.2)	27 (62.8)	43	
severe (25-70 degrees)	0 (0)	4 (100)	4	
Relation to curvature ($n = 47$)				
apical	13 (31.7)	28 (68.3)	41	0.193
coronal	4 (66.6)	2 (33.3)	6	
File type				
hand	39 (34.5)	74 (65.5)	113	0.276
rotary	33 (29.7)	78 (70.3)	111	
Level of separated fragment				
apical third	34 (22.4)	118 (77.6)	152	<0.001
middle third	30 (47.6)	33 (52.4)	63	
coronal third	8 (88.9)	1 (11.1)	9	
Clinical step when file separated				
while negotiating the canal	13 (54.2)	11 (45.8)	24	0.155
during cleaning and shaping	27 (25.5)	79 (74.5)	106	
after cleaning and shaping	2 (28.6)	5 (71.4)	7	
during gutta percha removal	7 (30.4)	16 (69.6)	23	
retreatment case	17 (35.4)	31 (64.6)	48	
unknown	6 (35.4)	10 (64.6)	16	
Case treatment type				
root canal treatment	38 (35.8)	68 (64.2)	106	0.260
retreatment	34 (28.8)	84 (71.2)	118	
total	72	152	224	

Table 2 Influence of separated fragment length on retrieval success

Variable	Success	Failure	P -value
Mean instrument length (mm)	5.2 (± 0.62)	1.9 (± 0.16)	0.005
Total number	72	152	

Mean separated instrument length in the treatment groups and results of independent sample t test

Table 3 Association between variables and likelihood of retrieval

Variable (test category/reference category)	b	Odds ratio	95% CI	P -value
Tooth type (anterior/posterior)	1.4	4.2	1.3-13.03	0.013
Level of separated fragment (coronal/middle and apical)	2.9	18.8	2.3-54.03	0.006
Fragment length	0.17	1.183	1.07-1.3	0.001

Results of simple binary logistic regression analysis, showing odds ratios (OR) and confidence intervals (CI) for independent variables

tooth type, the level of instrument fragmentation, and the length of the separated fragment.

For complete chemo-mechanical disinfection of the root canal system and successful treatment outcomes, it is recommended to remove instrument fragments, especially if the canal apical to the fracture has not been adequately cleaned [1,3]. Retention should be considered only when nonsurgical retrieval fails [8]. The outcome of endodontic treatment may be compromised by instrument fracture, particularly in the presence of a periapical lesion, with reduced healing rates [3]. In a systematic review and meta-analysis, Panitvisai et al. indicated that retaining an instrument fragment did not significantly alter the prognosis, noting no significant difference in healing rates between teeth with and without such fragments. However, treatment failure is more likely when such fragments prevent thorough canal cleaning, particularly in the presence of preoperative peri-radicular lesions [2]. Therefore, retrieval or bypassing of the fragment is essential for predictable outcomes.

In this study, out of 224 cases with separated instrument fragments, retrieval was successful in 32%. Bypassing was attempted for 152 fragments, achieving success in 95 cases, or 62% of attempts. On the other hand, a previous clinical study revealed only a 10% successful retrieval rate by PG residents for a total of 40 separated fragments [5]. Conversely, a higher successful retrieval rate (95%) has been reported in specialist practice [11]. Comparably to the present study study, a 52% retrieval success rate has been reported [9], although the sample size for the present study was significantly larger (224 teeth compared to 72 teeth). Differences in retrieval success rates may be attributed to variations in clinicians' expertise, tooth type, sample size, and management technique.

The present study revealed that the odds ratio for successful retrieval of separated instrument fragments was 4.2 times higher for anterior teeth than for premolars and molars. This accords with previous studies that have reported similar outcomes [8,9,11]. This disparity among teeth can be attributed to several anatomical and clinical factors. Anterior teeth generally have a more straightforward root canal anatomy, with single, wider, and straighter canals that facilitate easier access and instrument manipulation.

Moreover, the location of instrument fragments within the root canal system emerged as a critical factor influencing retrieval success. The present findings indicate that nearly 90% of instrument fragments at the coronal level were retrieved successfully. In contrast, the retrieval rates for fragments in the middle and apical thirds were markedly lower. The odds of successfully retrieving a separated fragment in the coronal third were 18.8 times higher than those for separations in the middle or apical thirds. These results are consistent with previous reports [5,8,11]. The relatively straight and wide anatomy of the coronal third facilitates better access and visibility, making fragment retrieval easier. Furthermore, the presence of a separated instrument fragment in the coronal third would probably be more noticeable, which might explain the higher rate of retrieval success, as reported previously [12].

A significant difference in the mean lengths of separated instrument fragments was observed between the retrieved and non-retrieved groups. The length of these fragments was found to significantly impact the likelihood of retrieval, with an odds ratio of 1.183, indicating that for every

one-unit increase in length, there is an 18.3% increase in the odds of successful retrieval. It was suggested that longer fragments might be easier to remove than shorter ones, positing that fragments longer than 5 mm are likely to engage the dentine at their tips. This engagement would create space coronally, facilitating loosening of the fragment [8]. Previous clinical studies have confirmed and supported a higher success rate for removal of longer fragments [9,10], but others found no correlation between fragment length and retrieval success [5,14]. The higher retrieval success for longer fragments can be attributed to increased visibility and the ease with which they can be grasped and manipulated. Longer instrument fragments protrude more prominently within the canal, providing better leverage points for retrieval tools.

The present study also examined the influence of canal curvature on the success of fragment retrieval. Notably, none of the instrument fragments in severely curved canals were retrieved successfully, whereas greater success was achieved in mild and moderately curved canals, consistent with previous studies [9,10,12]. However, this difference between canal curvature categories was not statistically significant, probably because of the small number of teeth with severe curvature ($n = 4$) in this study sample. Although the incidence of instrument separation is known to be greater in canals with severe curvature [8,22], within the present sample, general dentists may have been less likely to attempt treatment in such cases, opting instead to refer these challenging cases to PG residents or endodontic specialists. This might explain the limited number of severely curved canals with separated instrument fragments within the study sample.

This study was a retrospective evaluation of referrals received by PG residents in a university-based setting. Consequently, the distribution of teeth and the locations of the fragments may not have been representative of cases as a whole. Therefore, the results should not be generalized, and may not be applicable to other groups of general dental practitioners. Additionally, although various methods have been suggested previously for the retrieval of instrument fragments [8,23], the primary tools used for retrieval in the King Abdulaziz University postgraduate program are ultrasonic tips under observation with a dental operating microscope, an approach which has been found to improve the overall success of retrieval [10,12,20]. However, the program does not adhere to the viewpoint that instrument fragments must be removed in all cases. Instead, retrieval is undertaken only under optimal conditions, such as the excellent vision provided by magnification, with minimal loss of dentin structure. This background might also limit the generalizability of the results. Moreover, the inclusion of cases treated by PG residents would have ensured case homogeneity, creating a consistent treatment approach that would have strengthened the validity of the study findings. All of the residents followed a similar approach for management of instrument separation. However, variability among different levels of individual resident experience and skill cannot be dismissed, as this might have influenced outcomes.

This study was not without limitations. The retrospective nature of the analysis may have introduced selection bias and limitations, such as incomplete or inconsistent documentation. Although data retrieved from PG residents might be homogeneous, different findings may arise in cases derived from endodontists and more experienced clinicians. Radiographic findings were assessed using periapical radiographs. Although these are useful and accurate for detection of separated instrument fragments [24,25], they provide only two-dimensional images, which might hinder accurate assessment of anatomical variations, canal curvatures, and periapical conditions. In contrast, cone beam computed tomography (CBCT) can provide a more comprehensive and accurate evaluation of root canal morphology and associated pathologies [26]. Other variables that can be extracted from CBCT might also significantly influence the success of retrieval. Additionally, factors such as the period until retrieval and the visibility of the fragment were not reported, due to the study design limitations. Moreover, there was no standardized time limit for residents to attempt retrieval and abandon it if this period was exceeded. It was recommended that residents allocate a time slot of 45-60 min for the retrieval of instrument fragments. Further extension of the treatment time might reduce the success rate as a result of operator fatigue, the risk of secondary fractures, or excessive dentin removal, which can lead to fracture or perforation [14]. Accordingly, this study might have benefited from a standardized time allocated to each resident for attempting retrieval. Further studies will need to examine the effects of procedural errors, the remaining dentin thickness after retrieval,

and the long-term prognosis of teeth after management in relation to the success of fragment retrieval.

The present retrospective analysis has highlighted several critical factors influencing the retrieval of separated instrument fragments during endodontic treatment, including the tooth type, the level of fragment separation within the canal, and the length of the fragment. The study findings underscore the need for careful case selection when attempting to retrieve instrument fragments, in order to optimize treatment outcomes. Future research should aim explore the impact of procedural errors, remaining dentin thickness, and long-term prognosis in relation to retrieval success.

Abbreviations

CI: confidence interval; CBCT: cone beam computed tomography; OR: odds ratio; PG: postgraduate endodontic residents; mm: millimeters

Ethical Statements

Ethical approval for this study was obtained from the Institutional Research Board and the Research Ethics Committee at King Abdulaziz University Dental Hospital (KAUDH) (ethical clearance number 4568799).

Conflicts of Interest

The author has no conflicts of interest to declare in relation to the publication of this manuscript.

Funding

This project was funded by the Deanship of Scientific Research at King Abdulaziz University, Jeddah, under grant number (GPIP: 36-165-2024).

Author Contributions

SSZ contributed to all stages of the study, including conceptualization, methodology, formal analysis, investigation, data curation, writing – original draft, writing – review and editing, visualization, project administration, and funding acquisition. As the sole contributor, SSZ ensured the accuracy and integrity of all aspects of the research. In accordance with the ICMJE authorship criteria, SSZ takes full responsibility for all elements of the work.

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Acknowledgments

The author is thankful to Dr. Rahaf Al Balawi and Dr. Waad Al Ameer, whose efforts in collecting data were crucial for the study. Appreciation is extended to Dr. Hadeel Edrees for assistance in evaluating the periapical radiographs collected for the study. During the preparation of the manuscript, the author used Chat GPT 3 for proofreading, and improvement of writing and readability. Thereafter, the author reviewed and edited the content as needed, and takes full responsibility for the content.

Data Availability Statements

Data are available on request.

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