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Research Article

Procedural Errors Observed with Primary Root Canal Treatment Delivery in Teeth Taken for Non-Surgical Retreatment in a Dental College from Southern India

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Abstract

Introduction

This observational study was taken up with an aim to observe clinical and radiograph findings associated with primary orthograde root canal treatment failures from patients taken up for non-surgical root canal retreatment in a dental college from South India.

Methods

A total of 142 teeth taken up for root canal retreatment were included in the study. All the pre-, intra-operative radiograph and clinical mishaps and findings were recorded. A logistic regression analysis was done to assess the mishap factor influencing the presence of pre-operative symptoms.

Results

Mandibular molar teeth were most frequent teeth included for retreatment. Radiograph evidence of short of apex or inadequate obturation, missed canal and ledges were the most common errors observed. Mandibular incisors had significantly higher incidence of missed canal. Logistic regression analysis showed that obturation short of apex was significantly associated with symptomatic failed root canal treated teeth.

Conclusion

High percentage of endodontic errors was present in the teeth reported for retreatment with time passed less than 1 year since completion of primary root canal treatment. Coronal restoration failure was low. Inability to reach the root apex was significantly influenced by presence of post and separated instrument

Introduction

Root canal retreatment has been defined by American Association of Endodontists [1] and Carr [2] as a procedure that is performed on a tooth that previously had had attempted definitive treatment and now requires further treatment to ensure a successful result. Many authors have outlined the varied causes for root canal treatment failure [3-6]. A previous radiograph report on the presence of periapical radiolucency associated with root filled teeth from India observed a prevalence of 37.4% [7]. This study also concludes that periapical lesion was significantly associated with inadequate radiograph appearance of root canal treatment and coronal restoration. Findings from a Japanese study show that the main causes for root canal treatment failures were open apices, perforation and root fracture [6]. It was outlined in this report that majority of root canal treatment were performed by general practitioners a same scenario found in India [6,8,9]. But there is lack of scientific evidence regarding the clinical and radiograph details associated with failures of primary orthograde root canal treatment in Indian context. Therefore this observational study was taken up with an aim to observe clinical and radiograph procedural errors associated with primary orthograde root canal treatment failures from patients taken up for non-surgical root canal retreatment in a dental college from South India.

Materials and Methods

After obtaining institutional ethical committee approval the trial was registered in Clinical Trials.gov (NCT04250519). An informed consent was obtained from each patient or guardian as appropriate prior to the treatment. This study included failed root canal filled teeth taken up for non-surgical retreatment in the period from November 2018 to February 2020. Broadly the inclusion criteria were based in 3"D" process recommended by Machtou and Ruddle [10]. The inclusion criteria for this study are symptomatic teeth with radiographic evidence of previous root canal filling, asymptomatic teeth with inadequate root canal filling or treatment with presence of periapical radiolucency. Exclusion criteria were teeth with no evidence of root filling in any roots, with poor prognosis for post-endodontic restoration, poor periodontal condition, patients not willing for root canal retreatment, third molar teeth and radiograph evidence of extensive root resorption of more than 2/3rd length of root / roots.

All the teeth included in the study had pre-operative periapical radiograph taken using a PSP scanner (VistaScan Mini Plus; Durr Dental, Bietigheim-Bissingen, Germany) and paralleling cone technique (Densmart X-ray film holder; Universal X-rays, New Delhi, India). If the tooth had full coverage crown it was removed prior to periapical radiograph exposure. This periapical radiograph was assessed by an experienced Endodontist (corresponding author) under 2.5X magnification and optimal light conditions [11] for the following parameters,

a. Adequacy of the root canal filling quality was scored as (i) "inadequate" when obturation density or compaction is insufficient, voids / spaces evident between obturation material and root canal walls with obturation either short by > 2mm or reached root apex, when one of the canals has not been filled. (ii) "beyond root apex" with or without voids or spaces in obturation (iii) "short of root apex" when root canal filling material is short by more than 2mm with no spaces found in the obturation and (iv) "at the apex" with no spaces found in the obturation.

b. Evidence of separated instruments, perforations.

c. Root fractures

d. When more than one defect is present it was marked as "Multiple defects".

e. Periapical region evaluation was done using periapical index (PAI) [12].

For multi-rooted teeth, root with defective presentation was taken up for evaluation.

Clinical retreatment procedures were performed by 12 calibrated post graduate students in the corresponding author's department. Clinical and intra-operative radiograph details evaluated while performing retreatment procedures were,

i. Type of tooth

ii. Pre-operative pain scale assessment on 1 – 10 visual analog scale (VAS). 1 – 3 as mild, 4 – 7 as moderate and 8 – 10 as severe pain.

iii. Type of pre-operative symptoms viz., pain, swelling, pain and swelling, and sensitivity.

iv. Duration of the present symptoms in number of days.

v. Number of days / years before which the primary root canal treatment was done / attempted.

vi. Presence of missed canal/s in all teeth. In multi-rooted maxillary premolar and molar teeth mishap type of canal where the error has occurred.

vii. Ledges, separated instrument and perforations.

viii. Full coverage crown restoration.

ix. Post placed inside the root canals

x. Coronal restoration assessment was done as follows, (i) "Adequate" when there is no defect in restoration clinically and in radiograph (ii) "Fractured" when part of the restoration is missing with no evidence of breach into the pulp chamber or root canal space and (iii) "Lost" clinical and radiograph evidence of breach into the pulp chamber or root canal space because of either fracture or complete loss of coronal restoration.

In case of disagreement in evaluation the experienced corresponding author was consulted and a final decision was arrived.

Retreatment procedure

After administration of local anesthesia a rubber dam was placed in position. Endodontic access refining was prepared using tapered diamond burs (Mani Co., Tochigi, Japan) under copious water irrigation. Only the root/s with defective presentation the retreatment procedure was initiated in multi-rooted teeth. Gutta-percha removal from the root canal was done using Protaper universal retreatment files (Dentsply International Inc, OK, US). All the root canal retreatments were performed in two visits. Cleaning and shaping were performed using rotary files activated by an endodontic motor Endomate DT (NSK, Tochigi, Japan), and irrigation was performed using 3% sodium hypochlorite (Septodont, Healthcare India, Raigad, India). Working length estimation was done with electronic apex locators. Root variations in form of extra roots in maxillary and mandibular premolars, C-shaped root forms in maxillary and mandibular molars were recommended for CBCT scans. Instrument retrieval in canals with separated instruments was undertaken with ultrasonics (P5 Newtron, Acteon India, Gurugram, India and endosuccess retreatment tips, Acteon India, Gurugram, India) or instrument retrieval system (IRS® system, SD Swiss, San Diego, US) or H files (Mani Co., Tochigi, Japan) under operating microscope (Labomed Prima, Labo America, CA, US). Perforation sealing was done with Biodentine® (Septodont Healthcare Pvt Ltd, Raigad, India). Bypassing of separated instrument if retrieval was not achieved or ledge presence was attempted with placement /application of EDTA paste (RC prep, Stedman Pharmaceuticals Pvt Ltd, Chennai, India). Post removal was attempted with ultrasonic tips. Intra-canal medicament (Calcium hydroxide cement, Prime Dental, Thane, India) was placed at the end of first visit and tooth was temporarily sealed using zinc oxide eugenol cement (Prime Dental, Thane, India). At the second visit, root canal obturation was completed with single cone technique (Greater taper gutta-percha points, Diadent, Seoul, Korea) and zinc oxide eugenol sealer (Dental Products of India Ltd, Mumbai, India), or thermoplasticized gutta-percha (Super endo alpha and beta, B & L Biotech USA Inc, Fairfax, US) followed by permanent coronal restoration with composite. Thermoplasticized gutta-percha backfill with Biodentine® (Septodont Healthcare Pvt Ltd, Raigad, India) apical plug was used when the roots presented with resorption or periapical radiolucencies. Post treatment radiograph was taken to evaluate the retreatment procedure.

Root canal retreatment attempt was scored in three categories after completion of treatment by the corresponding author as,

i. Able to reach the root canal apex with complete removal of gutta-percha as evidenced in radiograph.

ii. Able to reach the root canal apex but with in-complete removal of gutta-percha in one or more canals as evidenced in radiograph.

iii. Inability to reach the root canal apex along with in-complete removal of gutta-percha in one or more canals as evidenced in radiograph.

Results

A total of 142 teeth (Figure 1) [74 (52.1%) males and 68 (47.9%) females] were included in the study. Figure 1 demonstrates mandibular molar [55 (38.7%)] was the most teeth taken up for retreatment followed by maxillary molar [32 (22.5%)] in the study. 4 mandibular molars had C-shaped root and 2 mandibular premolars had extra root / root canals and CBCT was taken for better management of these teeth and was counted with missed canal entry. The mean age of the patients was 33.04 yrs ± 12.24. 106 (74.65%) symptomatic and 36 (26.35%) asymptomatic teeth were recruited for the retreatment. Figure 2 presents distribution of different tooth types, with mandibular molar teeth having highest symptomatic teeth. Among various symptoms evaluated, pain was the most reported in 77 (72.6%) teeth followed by combination of pain and swelling in 25 (23.6%) teeth. In symptomatic teeth the mean pre-operative pain VAS score and duration of symptoms was 6.61 ± 1.85 and 39.15 ± 83.40 days respectively. The mean period before which the primary root canal treatment was attempted was 647.04 ± 734.57 days and it was significantly different in T-test (P = 0.021) between the symptomatic (557.36 ± 694.74 days) and asymptomatic teeth (911.11 ± 793.53 days). Figure 3 depicts time passed since the primary treatment. Mean PAI score was 2.52 ± 0.86. ANOVA test presented significant association (P = 0.00) with PAI score for time elapsed since the primary root canal treatment, as the score was ≥ 4 the mean primary root canal treatment attempt time duration doubled (Table 1). Pre-operative periapical radiograph assessment is presented Table 2 and is observed that most number of teeth was displaying obturation short of apex [71 (50%)] and multiple defects [59 (41.5%)]. Figure 4 depicts the clinical and radiograph status of coronal restoration, presence of full coverage crowns and post. Clinical and intra-operative radiograph examination details are presented in Table 3. It can be appreciated that missed canal and ledges as the most common type of procedural mishaps encountered in the retreatment procedure.

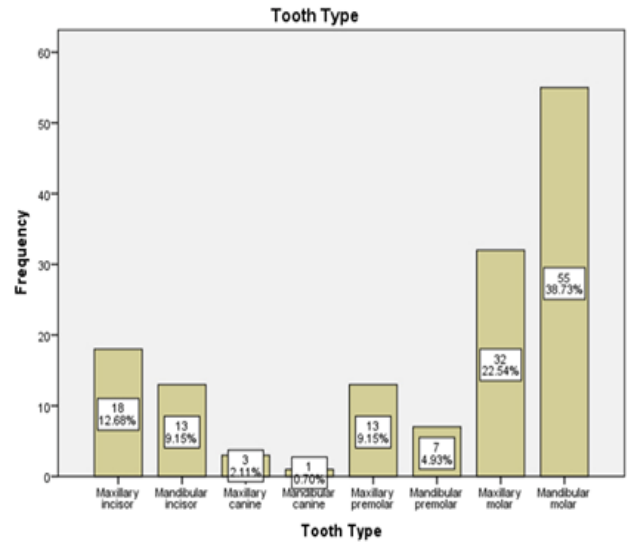

Figure 1: Distribution of different tooth types.

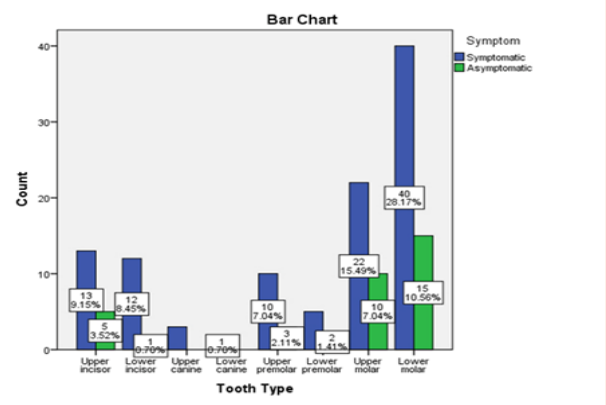

Figure 2: Distribution of symptomatic and asymptomatic tooth.

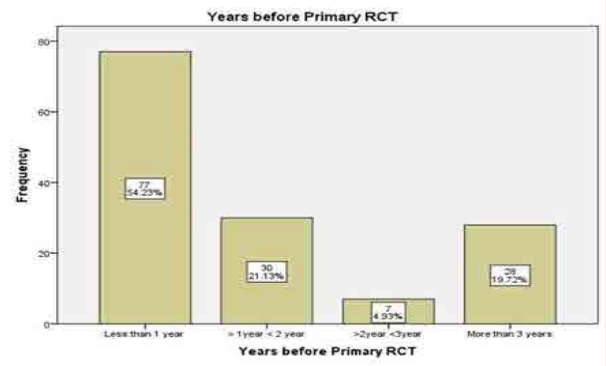

Figure 3: Length of time since the preceding primary root canal treatment attempt.

Figure 4: Clinical and radiograph status of (A) coronal restoration, (B) full coverage crowns and (C) posts.

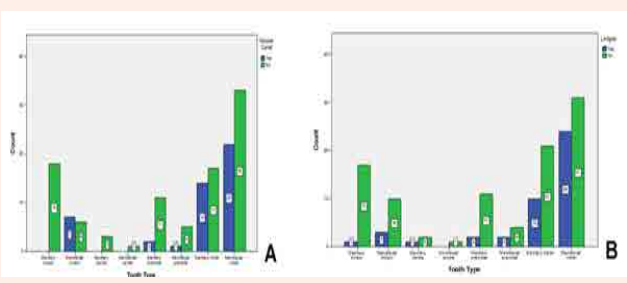

Figure 5: (A) Distribution of missed canal and (B) ldges among different teeth.

Table 1: Comparison between periapical index score (PAI) and mean time preceded since the primary root canal treatment attempt.

PAI score	N	Mean ± Standard Deviation
1	11	381.8182 ± 480.60000[a]
2	66	493.6970 ± 547.87629[b]
3	49	664.1224 ± 666.21257[c]
4	12	1192.0833 ± 1187.50781[d]
5	4	2062.5000 ± 1084.26242[e]
Total	142	647.0493 ± 734.57066

Source: *Different superscript alphabets represent significant difference (P < 0.05) in ANOVA test.

Table 2: Radiograph procedural errors detected in primary root canal treatment.

Obturation inadequate	52
Obturation beyond apex	7
Obturation short of apex	71
Obturation at the apex	12
Separated instrument	1
Perforations	1
Root Fracture	1
Multiple defects	59

Table 3: Clinical and intra-operative radiograph findings.

Missed Canal	Yes	48 (33.8%)
	No	94 (66.2%)
Separated Instrument	Yes	13 (9.2%)
	No	129 (90.8%)
Perforation	Yes	8 (5.6%)
	No	134 (94.4%)
Ledges	Yes	45 (31.7%)
	No	97 (68.3%)
Root Fracture	Yes	2 (1.4%)
	No	140 (98.6%)

Table 4: Ledges and missed canal detection in comparison to radiograph diagnosis for obturation quality.

		Missed canal		Ledges	
		Yes	No	Yes	No
Obturation	Short of apex	23 (32.4%)a	48 (67.6%)	26 (36.6%)	45 (63.4%)
	Beyond apex	-	7 (100%)	-	7 (100.0%)
	At apex	9 (75%)b	3 (25%)	1 (8.3%)	11 (91.7%)
	Inadequate	16 (30.8%)c	36 (69.2%)	18 (34.6%)	34 (65.4%)

Source: *Different superscript alphabets represent significant (P < 0.05) in Chi-square test.

Table 5: Ability to reach the root apex in comparison with various clinical and radiograph findings.

		Radiograph FINDINGS		Obturation								Missed Canal				Separated Instrument				Ledges				Post Restoration			
		Multiple defects		Short of apex		Beyond apex		At apex		Inadequate		Yes		No		Yes		No		Yes		No		Yes		No	
Retreatment	Able to reach the apex and complete removal of GP	55[a]	41.40 %	66[a]	49.60 %	4	3.00 %	12	9.00 %	51	38.30 %	45	33.80 %	88	66.20 %	11[a]	8.30 %	122	91.70 %	42	31.60 %	91	68.40 %	1[a]	0.80 %	132	99.20 %
	Able to reach the apex and incomplete removal of GP	2[b]	28.60 %	3[b]	42.90 %	3	42.90 %	0	0.00 %	1	14.30 %	2	28.60 %	5	71.40 %	-[b]	-	7	100.00 %	2	28.60 %	5	71.40 %	-[b]	-	7	100.00 %
	Inability to reach the apex and incomplete removal of GP	2[c]	100.00 %	2[c]	100.00 %	0	0.00 %	0	0.00 %	0	0.00 %	1	50.00 %	1	50.00 %	2[c]	100.00 %	0	0.00 %	1	50.00 %	1	50.00 %	1[b]	50.00 %	1	50.00 %

Source: *Different superscript alphabets represent significant (P < 0.05) in Chi-square test

It could be seen from Tables 2 & 3 that number of teeth with separated instrument and perforation is varied, this is because some of these teeth also had other defects and noted with multiple defects and in some other teeth they were only to be detected upon clinical and intra-operative radiograph assessment. Significantly (Chi square test P = 0.008) mandibular incisors had the highest proportion of missed extra canal followed by molars and mandibular premolars (Figure 5A). Significantly (Chi square test P = 0.00) increased proportion of mishap was seen in mesio-palatal canal (MB 2) of maxillary molars [12 (44.4%) teeth] followed by second distal canal [16 (32.6%)] canals, mesio-buccal (MB) [15 (30.6%)], and mesio-lingual (ML) [15 (30.6%)] of the mandibular molars. Figure 5B depicts that ledges were encountered in higher proportions in mandibular molars and premolars followed by maxillary molars and mandibular incisors these are the similar tooth accounting for most missed canals management. Pre-operative radiograph obturation at the apex had significantly (Chi-square test, P = 0.005) increased incidence of missed canal [9 (75%) teeth] (Table 4) especially in the premolars and molars; and pre-operative radiograph diagnosis with short of apex or inadequate had increased presence of ledges at 26 (36.6%) and 18 (34.6%) teeth respectively. Mandibular molar teeth with radiograph obturation evaluation of short of apex [14 (51.9%) teeth] or inadequate [10 (55.6%)] had significant association (Chi-squared test P = 0.023) with ledge presentation, and mandibular premolar [2 (66.7%) teeth] and maxillary molar [7 (43.8%) teeth] with radiograph diagnosis of short of apex had also higher incidence of ledges. Logistic regression analysis of radiograph and clinical mishaps showed that pre-operative symptom presence was significantly associated (P = 0.042, CI 0.158 – 0.965) with radiograph interpretation of "obturation short of apex". Retreatment procedure was able to reach the root canal apex in 140 (98.6%) teeth (Table 5). Two premolars a maxillary and mandibular were not able to be reached till the root apex. Evaluation of factors influencing the inability to reach the apex depicted significant association (P < 0.05) in Chi square test with following parameters (i) radiograph evaluation of multiple defects, obturation short of apex, (ii) presence of separated instrument, and (iii) presence of post (Table 5).

Discussion

The purpose of this study was designed to identify clinical and radiograph findings associated with primary orthograde root canal treatment failures from teeth taken up for non-surgical root canal retreatment in a dental college from South India. Similar to previous investigation [11] detailed protocols followed for primary root canal treatment was varied and inaccessible / non-reliable, therefore necessitating multiple pre- and intra-operative factors to be collected when patient presented for retreatment. A high percentage of procedural errors in observed root canal treatment delivery in this study it is likely that the primary root canal treatment been performed by non-specialists similar to findings by *Olcay et al.*[5] Age and distribution of the present findings corroborates with an earlier report [5]. In agreement with suggestions by *Olcay et al.* [5] patients experiencing pain was the main motive for consultation and mandibular molar teeth were the most frequent to fail. Reason proposed for higher frequency of mandibular molar was this is the first molar tooth to erupt and exposed to higher cariogenic challenges necessitating more requirement for primary root canal treatment in these teeth [5]. Time passed since the primary treatment analysis show 77 teeth (54.23%) presented in less than 1 year after completion, this is in accordance to earlier report [5]. Analysis of the time of primary root canal treatment attempted in the present study is in agreement to recommendation by *Ng et al.* [11] suggesting a follow up period of minimum 3 years for treatment to be assumed success as the present result of asymptomatic teeth taken for retreatment had primary root canal treatment attempt close to 3 year. Significant difference between PAI score and primary root canal treatment attempt duration may be related to time required for periapical lesion to form, but since the initial status of these teeth were not known this assumption could not ascertained with certainty. But previous reports have also concluded that teeth with large periapical radioluciencies have reduced pain after root canal treatment probably related to space available due to bone resorption for release of inflammatory pressure [13]. The cause of these periapical radioluciencies in the current study could not be found accurately whether they are result of failed root canal treatment or pre-existing lesion present at the time of initial treatment itself which has not healed. With probable reduced incidence of pain in teeth with large periapical lesions at earlier stages could have lead to patients sort retreatment at a later stage. High standard deviation in primary root canal treatment attempt time of the present study is because the pre-primary treatment pulp and periapical status of teeth was not accessible and also recruiting both symptomatic and asymptomatic teeth. Pre-treatment status has been shown to have an excellent correlation with post-treatment symptom presentation [13].

Obturation short of apex significantly influencing the pre-operative symptom of failed root canal treated teeth corroborates with earlier report [5,11]. Strindberg demonstrated that significantly lower success rates for root canal treatment in teeth with apically inaccessible canals and been acknowledged by other works [11, 14-17]. Role of pre-operative radiograph assessment in detecting the technical cause of root canal treatment failure was limited as errors like separated instruments, missed canals, ledges and perforations could be ascertained only after the retreatment initiation this is in agreement with earlier findings on radiograph examination [18,19]. An increased association of premolar, molar radiograph presentation of short of apex or inadequate was observed with ledge observation in agreement with earlier conclusion [20]. Missed canal having increased influence on root canal treatment failure is in correlation with earlier findings [21,22]. Mandibular incisors with two canal incidence are from 11.3 to 88.7% [23]. Present findings in mandibular incisors with significant missed canal is in accordance to the incidence cited above, and clinician should be more aware that single rooted mandibular incisor should be considered two canal teeth unless not detected while performing the root canal treatment. Maxillary molars were the next highest teeth with missed canal and mishaps significantly occurred with mesio-palatal canal. This is in acceptance of findings of two canal presentations in mesio-buccal root of maxillary molars are from 36.1 to 96.1% [23]. Besides the mandibular incisors and maxillary molars, mandibular premolars [more than one canal system 9 to 24%] and molars which have also been established in previous reports of increased canal complexities [23- 25] had higher incidence of ledge presentation associated with missed canals. Our results depict pre-operative radiograph presentation of obturation at the apex with no defects had significant correlation with detection of missed canal in agreement to an earlier conclusion [19]. Radiograph of failed root canal treated teeth with obturation at apex should alert the operator about the presence of additional canal in teeth with increased propensity for additional canal presentation. Missed canal diagnosis was made intra-operatively and pre-operative radiograph assessment was not utilized for this purpose as earlier findings have shown that radiograph are not proper tool for detecting additional / missed canal [18,21,22]. Vast majority of procedural errors encountered in this study was obturation short of apex or inadequate, multiple radiograph defects and missed canals similar to findings by Hoen and Pink [19].

Coronal restoration inadequacy was not a common contributing factor for root canal treatment failure in our data this was contrary to other reports [5,11]. This difference may be explained by the fact an appropriate coronal restoration can improve the success of primary root canal treatment only when root canal management was performed with adherence to all the necessary protocols. Higher percentage of procedural errors and the length of time since the preceding primary root canal treatment of this present study indicate that when the technical quality of initial root canal treatment is compromised the treatment failure occurs within 1 year. Retreatment attempt and ability to reach the root apex of current observation is 98.6%, this was possible because of access to advanced

armamentarium like retreatment rotary instruments, instrument retrieval systems, operating microscope, ultrasonic devices and bioactive endodontic cements [26]. Two premolars with inability to reach the root apex had presence of separated instrument, and radiograph examination pointed to multiple defects; of this one premolar had fibre post. Separated instrument incidence in the present result is low compared to other mishaps the reasons for this can be multi-folded (i) Separated instruments did not cause any significant failure rate in the population observed or (ii) occurrence of separated instruments in the population observed is minimal. Ability to remove the broken instrument or bypassing it is influenced by multiple factors these were not accounted for it in the methodology [10]. A significant association of separated instrument presence in hindering the ability to reach the root apex reinforces the concept that best antidote to broken instrument is prevention [10]. Similarly relatively low incidence of teeth encountered with separated instrument pegs back to discussion upon prognosis of leaving versus removal of separated instrument [10,27]. Presence of fibre post has been termed to be difficult to remove and is dependent on multiple factors this was reinforced by the results of this investigation [10]. Therefore, canals with presence of separated instrument or posts taken up for retreatment has to be cautiously weighted for risk versus benefit [10]. Gorni and Gagliani demonstrated that procedural errors are as important as microbiological ones for success of primary root canal treatment a view echoed by other authors [27,28]. Higher percentage of procedural errors in our data correlates with this summary. One of the drawbacks of this report is the failure to account for biologic factors attributing to root canal failures. Future studies from India could be designed to analyse about the role of biologic / microbial factors in root canal treatment failure.

Conclusion

Intra-operative radiographs and clinical assessment while performing retreatment procedures are essential in ascertaining the reason for failure along with pre-operative radiographs. Obturation short of apex, multiple defects, missed canals and ledges were the common procedural errors observed. Coronal restoration failure was low. Inability to reach the root apex in retreatment was significantly influenced by presence of post and separated instrument. The authors contend that thorough knowledge of canal anatomy, meticuluous details of treatment protocols and clinical application of these details are essential in minimizing root canal treatment errors.

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