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REVIEW ARTICLE

Solution methods of instrumentation related complications in endodontic treatment

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Abstract

Background: Endodontics is a skill that requires the use of precision instruments in tight spaces and is a complex discipline often underestimated by clinicians and patients. Inevitably, this will lead to complications. Complications encountered during endodontic treatment occur during diagnosis, anesthesia, cleaning, and shaping of the root canals and filling the root canals. Complications can occur at any stage of treatment. The various procedures associated with root canal treatment can be divided into three treatment phases: Pre-operative, operative, and post-operative. Since endodontic complications may occur at any of the pre-operative, intraoperative, and post-operative stages, complications that may develop are also classified in the same way. **Aim:** In this review, operative complications including instrument fracture, ledge formation, canal obstruction, apical transportation, and strip perforation that may occur during canal preparation in endodontic treatment are discussed. **Conclusion:** Technological developments in endodontics have revealed methods and instruments enable successful treatment of calcified root canals, severe canal curvatures, ledges, resorption defects, perforations, and broken canal instruments without complications. **Clinical Significance:** Therefore, the physician should always be ready to manage complications. The task of the physician is to know how to avoid potential complications and how to manage complications that may arise during treatment.

Keywords: Canal preparation, Complication, Root-canal treatment

Introduction

Endodontics is a skill that requires the use of precision instruments in tight spaces. Inevitably, this will lead to complications.[1] Complications may occur at every stage of treatment. Therefore, the physician must always be ready to manage complications. The physician's task is to know how to avoid potential complications and manage complications that may arise during treatment.[2]

In relation to root canal treatment, complications can be classified as pre-operative, intraoperative, and post-operative. Intraoperative complications may occur during anesthesia stage, preparing access cavity, cleaning, and shaping the root canal or filling the root canals. Among these, complications related to root canal preparation during the cleaning and shaping of root canals can be entitled as instrumentation related complications.

The aim of the present article is to discuss the instrumentation related complications including instrument fractures, ledge formation, canal obstruction, canal transportation, and strip perforation that may occur while preparing the root canals in the operative stage [Table 1]. Solution methods of these complications are also discussed.

Instrument Fracture

Instrument fracture is a common complication in endodontic treatment, particularly in narrow or curved canals, with improper or overuse of instruments,[3] especially in molar teeth with the highest degree of root curvature.[4] A wide variety of broken instruments have been reported in the root canal system; however, much of the literature consists of fracture studies of K-type stainless steel (SS) hand files, and Nickel-Titanium (NiTi) rotary files.[5]

Fracture rate of NiTi files is 1.3–10.0% and the fracture rate of SS hand files is 0.25–6%.[5,6] The major reason for the higher fracture rate of NiTi files, which has been stated to be superior to SS hand files due to their flexibility, torsional fracture, and corrosion resistance, is difficulty in recognizing the deformation of the file.[7]

Factors affecting prognosis are; whether the tooth is vital or not when the fracture occurs, the location of the broken piece in the canal, the taper and size of broken piece, and type of broken instrument.[3,8]

Causes of Fracture

It has been emphasized that 91% of fractures are caused by cyclic fatigue, 3% by torsional fatigue, and 6% by a combination of both.[9]

Torsional fracture occurs as a result of exceeding the elasticity limit when the body part wants to continue to rotate despite the compression of the tip of the file in the canal.

Flexural fracture occurs due to cyclical fatigue that occurs as a result of the continuous exposure to tension and compression during repeated use of the file in curved canals.

Numerous factors play a role in instrument fractures including skill and experience of the physician, preparation technique used, insufficient irrigation, dynamics of the use (speed and torque value), number of uses, design, sterilization cycle of the files, and anatomical configuration of canals.[10,11]

Approach to Fracture

Fracture management includes orthograde or surgical approaches. Orthograde approaches include removing/passing

Table 1: Causes, management procedures, and steps for prevention of instrumentation related complications

Complication	Causes	Management	Steps for prevention
Instrument fracture	Skill and experience of the physician Preparation technique used Insufficient irrigation Dynamics of the use (speed and torque value) of rotary files Number of uses, design, sterilization cycle of the files Anatomical configuration of canals	Broken piece removal Bypass of broken piece Filling over broken instrument Surgical procedures	Abundant irrigation Not to force instrumentation Limit the number of uses of instruments Careful evaluation of anatomical variations
Ledge formation	Insufficient access to the apical Root canal curvature Incorrect root canal length determination Excessive forced instrumentation Incorrect apical use of instruments Pushing the debris apically	Trying to cross the ledge under abundant irrigation Normal preparation up to the ledge under abundant irrigation Use of thermoplasticized gutta-percha and fluid consistency canal sealer in filling stage	Use of files with pre-beveled in a curved canal Use of instruments sequentially Sufficient irrigation Avoid excessive use of chelating agents Sufficient Access cavity width
Canal transportation	Asymmetric removal of dentine due to uneven force distribution in curved root canals Excessive removal of dentin in some areas of root canal	Cannot be corrected	Avoid use of instruments with large apical diameters in narrow canals Not apply excessive force Use of by pre-beveled stainless steel instruments Increase the duration of use of small-diameter files Avoid duration of use at the apical with rotary instruments Make modifications to reduce the cutting efficiency of instruments Use of balanced force and step-back tecniques
Canal obstruction	Pushing dentin chips, debris, pulp tissue or restorative materials to the apical Insufficient irrigation Not cleaning the debris accumulated between the grooves of the files Ignoring the recapitulation process Use of step-back technique, anti-curvature technique and circumferential filling	Detection of weak point by 08–10 K type SS hand file with a clockwork movement until it reaches the working length Endosonics can be used to dislodge dentine chips under the influence of acoustic flow	Use of balanced force and crown-down techniques Abundant irrigation Cleaning the files and working with clean files in every steps of the preparation
Strip perforation	Uncontrolled use of gates Glidden bur during root canal shaping Over-preparation Improper instrumentation	Routine canal treatment without applying too much pressure to the root canal and perforation area in small perforations Filling the entire canal with materials such as mineral trioxide aggregate and biodentine Apical resection	Avoid excessive use of H type SS hand files Prebeveled use of files in curved canals Use of NiTi files with balanced force technique Controlled and selective shaping of each canal

the broken piece or cleaning and shaping the root canal to the level of the broken piece.[12] The first thing to do is to take a radiography and decide which approach to apply.

Broken Instrument Removal

Optimum treatment option is removal of the broken piece to complete endodontic treatment effectively.

Broken instrument removal requires an experienced, knowledgeable physician and has adequate equipment, in which complications such as perforation, ledge formation, and transportation may occur, so it may further endanger the prognosis of the tooth. It is affected by several factors:

- Anatomical factors: Location, length, and curvature of the root, root canal's cross-sectional shape and diameter, broken piece location in the root canal should be taken into consideration in the removal operation. In this context, fractured piece found in the anterior teeth compared to the posterior teeth, in maxillary teeth compared to the mandible, in the coronal third compared to the middle or apical third, occurrence in the coronal of the curvature compared to its apical increases the likelihood of removal as it becomes more visible and accessible[13]
- Type of broken instrument: NiTi rotary files are generally more difficult to remove than SS hand files because they are usually broken into dentin against the outer wall of the canal due to their flexibility in curved canals.[14] On the other hand, removal is more difficult in H type hand files due to the greater helix angle and deeper grooves compared to K type files[13,15]
- Length of broken instrument: It is easier to see and access and also to remove when a long piece left. The success rates of broken instrument removal in cases where length is less than 5 mm; between 5–10 mm and 10–15 mm; have been reported to be 62%, 79% and 89%, respectively.[10] The researchers stated that since the ends of the long pieces are stuck in the dentine, there is a gap in the coronal part for bypass, which made it easier to remove the broken instrument. Knitting technique is known to be successful in removing long pieces[16]
- Factors dependent on the physician: Level of knowledge and education, familiarity with technique and equipment used, determination, and creativity of physician significantly affect the success rate.[17]

Broken Instrument Removal Procedures

Although, there is not yet a standard procedure for broken instrument removal, studies have reported that Masserann and ultrasonic devices are successful.[13]

- Masserann Kit: Masserann set consists of 14 hollow inserts with a diameter of 1.1–2.4 mm (sizes 11–24) and two extractors (tubes in which the file or piston is inserted).[18]

Trepan burs are used counter-clockwise to prepare a gap around the coronal portion of the piece.[19] The tip of the file or the piston, which is passed through the extractor tube, is placed in the space formed around broken part. After this insertion, when the file or piston is compressed, the free part of the piece is locked between the file end or the piston and the inner wall of the extractor.

Relatively large diameters of the extractors lead to remove significant amount of dentin, which can reduce the root strength and cause perforation or fracture. Therefore, masserann set has been suggested to be used in straight root canals where the broken instrument is easily accessible, rather than in difficult areas such as the apical third of curved or narrow root canals.[20]

- Ultrasonic systems: The first purpose of using ultrasonic system is to ensure that the broken part can be seen clearly without obstacles. Therefore, coronal portion of the fracture should be expanded using modified gates Glidden burs or ultrasonic tips. After broken piece is clearly seen, it is aimed to be removed by exposure to vibration with ultrasonic tips. Ultrasonic tip should be used with counter-clockwise movements. It should only be in contact with the broken piece without any contact with the coronal dentine. It should not be used with excessive pressure because of possibility of the broken piece being pushed apically[21]
- Canal finder system: Canal finder system (FaSociete Endo Technique, Marseille, France) consists of a handpiece and specially designed files. The system produces a vertical movement with a maximum amplitude of 1–2 mm that decreases with increasing speed. Hence, specially designed file grooves are mechanically clamped with the broken piece. Thus, it can be loosened or removed.[22]

Bypass of Broken Piece

The aim of fractured instrument removal procedure is not only to remove broken piece but also to maintain the integrity of the tooth. Thus, if possible, passing alongside a deep located or beyond the curvature of the root canal located broken piece may be appropriate treatment option.[13,23]

Based on the fact that none of the root canals are perfectly round and there is a small gap between the root canal wall and the broken tool, the "by-pass technique" allows a smaller file to skip the broken piece. This technique is performed by rotating and pulling a small numbered K-type hand file with a pre-beveled tip a quarter turn or applying it as a clockwork movement.[24]

It is possible to create a secondary canal parallel to the original, which may lead to a root perforation when attempting to bypass. In addition, ledge formation, secondary fracture of fragment, movement of the part to the apical and full part extrusion are the complications that should be expected.[24,25]

Bypassing can also dislodge the broken piece by minimizing contact between the broken instrument and root canal walls. It also provides enough space next to the part for instruments such as ultrasonic tips to enter. Thus, bypass can be considered as a first step, since in most cases the broken tool can be removed after bypassing.[25]

Filling Over Broken Instrument

Broken instrument may be left in the root canal. In this situation, the coronal of the broken instrument should be treated according to standard endodontic procedures.[25] This option is particularly applicable if the fractured piece is located beyond the curvature in the apical third or occurred in the final stages of preparation. Patients should be followed-up clinically and radiographically. If symptoms develop, surgical approaches may be considered.

Surgical Approach

Surgical procedures may be required, when conservative treatment fails. In addition, periapical lesions negatively affect the success of root canal treatment. Hence, if instrument is broken in a tooth with periapical lesion and the fractured part is inaccessible, surgical approach may be considered as the most appropriate treatment option.

Surgical treatment includes apical surgery, deliberate replantation, root amputation, or hemisection.[26]

Ledge Formation

Ledge formation is deviation of original canal curvature, usually without communication with the periodontal ligament, in the external slope of curvature. Ledge usually occurs when files are used shorter than the canal length and canal is blocked at that "short point."[27]

Ledge formation can result in incomplete instrumentation without proper irrigation, reducing the likelihood of obtaining an adequately shaped canal that reaches the ideal working length. Thorough cleaning and shaping of the root canal at the apical of the ledge are difficult; therefore, ledge formation often negatively affects the success of endodontic treatment.[28] Studies on the incidence of ledge formation have found a wide range of results between 10% and 41%.[28-30] Furthermore, molar teeth with curved root canals have been reported the most susceptible.[28,31-33]

Factors such as insufficient access to the apical part of the canal due to insufficient cavity width, incorrect evaluation of curvature direction, incorrect root canal length determination, excessive forced instrumentation, using files without pre-beveled in a curved canal, not using the instruments sequentially, insufficient irrigation and excessive use of chelating agents, incorrect apical use of instruments during preparation, and pushing the debris apically play a role in the etiology.[28,34]

Apart from these, factors such as instrumentation technique (step back application and balanced force technique reduce the risk of ledge formation), root canal curvature, tooth type, and canal placement are associated with ledge formation.[27,28]

Defining the Ledge

Defining the ledge requires clinical and radiographic observation. Once the ledge is formed, the file no longer goes to the working length,[28] the characteristic tactile feeling felt in apex narrowing is replaced by the feeling of hitting a solid wall.[35] File should be placed in canal and radiographs should be taken using parallel technique when ledge formation is suspected.

Ledge Formation Management

Factors that mostly affect success in skipping a ledge are size of the file responsible for its formation and extent of the width of canal at the apical of ledge formation. Root canal preparation should be stopped immediately when ledge formation is suspected. To bypass the ledge and restore access to the apex, the shortest (to increase the sense of touch and the force to be applied), pre-beveled, 08-10-15 size K-type hand files should be used under abundant irrigation. Files should be used with "watch-winding" and "picking" movements at short amplitudes to capture a gap. When resistance is encountered during these movements, the file should be slightly retracted and rotated, and same movements should be repeated until it passes the ledge.[36]

Focusing on keeping the file apical to the ledge, tip of the file should be used with very short push-pull movements. If the file begins to move freely, it must be used as a longer push and pull movement by leaning against the wall where the ledge is located or by turning clockwise while removing to reduce or eliminate the ledge.[36] At this stage, care should be taken that the file does not become flattened.

If the ledge is not crossed, the root canal can be prepared normally under abundant irrigation (due to the possibility of extending beyond the ledge) up to the ledge. Thermoplasticized gutta-percha and fluid consistency canal sealer are used in filling stage.[35]

Canal Transportation

Due to tendency of the files used in curved canals to return to their original form during preparation, uneven force distribution occurs in certain areas (at the outer part of the curvature at the apical and the inner part of the canal at the coronal). This situation causes asymmetric removal of dentine, altering the original anatomy of the canal.[37]

Canal transportation is a complication that occurs in most of the curved canals, regardless of instrumentation technique or instrument type. Risk of canal transportation increases as the angle of curvature gets higher especially in mesial roots of mandibular and maxillary molar teeth.[38] It is difficult to detect clinically and cannot be corrected when it occurs. As the amount of transport increases, displacement of the apical foramen, zip, and elbow formation can occur.[39]

Zip is an elliptical shape formed at the apical of root canal transported with the preparation along the outer direction of the curvature. Elbow is a constriction caused by excessive preparation of the inner part at coronal and outer part at apical of the curvature, making it difficult to clean the apical part.[40]

The claim that canal transportation is a direct cause of treatment failure is controversial. Inability to completely remove

remaining microorganisms and fracture risk due to excessive removal of intact dentine in some areas within the canal are shown as the main causes of failure.[33]

The most important goal in canal transportation is to minimize the occurrence. Therefore, there are some points to be considered especially in curved canals:[37,39,40,41]

- Avoiding the use of instruments with large apical diameters in narrow canals
- Not applying excessive force while using the instruments
- Using SS instruments by pre-beveling
- Increasing the duration of use of small-diameter files in preparation
- Avoiding duration of use at the apical with rotary instruments
- Making modifications to reduce the cutting efficiency in some parts of the instruments
- Using preparation techniques such as balanced force and step back.

Canal Obstruction

Canal obstruction is a complication caused by pushing dentin chips, debris, pulp tissue, or restorative materials to the apical during preparation. It causes loss of working length, preventing access to most apical part of root canal system and preventing complete disinfection. It has been reported that canal obstruction occurs most frequently in canals prepared with step-back technique, anti-curvature technique and circumferential filling, and least when balanced force and crown-down technique are used. Failure to pay attention to irrigation, not cleaning the debris accumulated between the grooves of the files, and ignoring the recapitulation process are among the causes of canal obstruction.[40,42] Besides, there is no clear information about its incidence in the literature.

There is a characteristic, almost solid but "penetrable wall" tactile sensation unlike the feeling of the instrument hitting a solid wall in the detection of canal obstruction. If canal obstruction occurs, 08–10 K type SS hand file is rotated circumferentially to find the weak spot in the occlusion area under abundant washing with chelating agents. After the detection of weak point, the file is used with a clockwork movement until it reaches the working length. If problem is not solved, endosonics can be used to dislodge dentine chips under the influence of acoustic flow. In any case, the file should not be overstrained as it can further compress the dentin debris and worsen the condition.[36,43]

Strip Perforation

Strip perforations occur mostly in the middle and apical third of the root, as a result of uncontrolled use of gates Glidden bur during root canal shaping, over-preparation, or improper instrumentation. Strip perforation is generally seen in areas of minimal dentin thickness; such as distobuccal roots of maxillary molars, surfaces of mandibular molars facing the furcation, and C-shaped root canals in mandibular molars.[44] Root perforations have an incidence of approximately 10% among all endodontic complications.[45]

In some cases, strip perforation occurs in a thinned canal wall by a pre-existing external root resorption. However, it may also occur during elimination of the steps, attempts to open the obstructed canals, removal of the gutta-percha belonging to the previous treatment, preparation or removal of the post cavity or removal of the broken instrument.[43]

Strip perforation differs from other perforations in that the large area affected the irregular edge of the perforation area, and the difficulty in sealing the perforation. It can induce mechanical trauma to surrounding tissue, leading to periodontal inflammation. The root becomes susceptible to fractures, which can result in tooth loss directly due to loss of radicular dentin.[46]

Protection from Strip Perforation

It is necessary to avoid excessive use of H type SS hand files, which are used with push-pull movements. If preparation is made in a curved canal, it must be used with pre-beveling. Appropriate shaping methods should be used with Ni-Ti files (balanced force technique).

Controlled and selective shaping of each canal is a convenient way to prevent strip perforation. Particular care should be taken in preparing the post cavity for roots with a kidney-shaped cross section (palatinal root of the upper molar and distal root of the lower molar). The prepared post space should center the canal as much as possible. Anesthesia should not be used during the procedure.[44]

Perforation Repair

Perforations occurring in the middle third are very difficult to control. It is necessary to position the instruments toward the original canal, so pre-beveled instruments must be kept away from perforation.

There are two options for closing these perforations after bleeding is stopped:[47]

- The first technique is to fill apical part of perforation area with gutta-percha, so the remaining part can be covered with repair material. The disadvantage is risk of obturation materials overflowing into the perforation area during filling of the apical part
- The second technique aims to cover the perforation area first. The apical part of the perforation is closed with a gutta percha or paper point to avoid overflowing of repair material. After the perforation is repaired, the entire canal is filled with heated gutta-percha

If the perforation occurs at the apical, its size is small and there is access to the main canal, routine canal treatment can be performed without applying too much pressure to the root canal and perforation area. However, if the perforation is large, the entire canal should be filled with materials such as mineral trioxide aggregate and biodentine because of better sealing

properties. Apical resection should be considered especially in teeth with apical periodontitis.

Conclusion

Despite technological advances in the field of dental instrumentation and materials, endodontic errors persist. Endodontic procedure errors are not the direct cause of treatment failure. Technological developments in endodontics have revealed methods and instruments enable successful treatment of calcified root canals, severe canal curvatures, ledges, resorption defects, perforations, and broken canal instruments without complications.

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