MANAGEMENT OF ENDODONTIC IATROGENIA: A REVIEW

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Abstract
Introduction. Endodontic iatrogenia, such as iatrogenic perforation, formation of ledges, blockage of canals, instrument breakage, unaddressed anatomical complexities, can have a substantial impact on the long-term outcome of endodontic treatment. The most frequent complications during endodontic treatments are root canal perforations, ledges, and instrument fractures. *Prevention and management*. Endodontic iatrogenia can be prevented by the use of AAE's assessment tool (low, moderate, high difficulty cases), operator microscope, static/dynamic guided endodontics systems. Steps in management of endodontic iatrogenia consists of: assessment and diagnosis, communication with patient, immediate management, referral to specialist for non-surgical or surgical approach if necessary, monitorisation of healing process. *Conclusions.* Clinicians must possess a comprehensive understanding of the causes, prevention strategies, and reliable corrective measures for specific endodontic iatrogenia. Endodontic iatrogenia must be managed by individualised therapeutic approach using effective instrumentarium and biomaterials for positive long-term outcomes. Interdisciplinary collaboration of general dentist with specialists (endodontic specialist, oral surgeon) can be required in complex cases.
Key words: endodontic iatrogenia, prevention, management, non-surgical, surgical

1. Introduction

The primary objective of root canal treatment is to meticulously cleanse the infected root canal system through mechanical and chemical means. Subsequently, the cleaned root canals are sealed with a filling material [1]. The key to a successful outcome lies in eliminating infected substances and preventing any additional intraoperative or postoperative infections. The failure of root canal treatment can be attributed to the presence of infectious materials within the root canal itself or in adjacent areas [2].

Recent advancements in endodontic treatment technology have enabled the preservation of teeth once considered beyond repair but technology, instruments, and materials should complement rather than replace a clinician's clinical expertise and experience [3].

Endodontic iatrogenia refers to complications or errors that occur during root canal treatment. Endodontic iatrogenia, such as iatrogenic perforation, formation of ledges, blockage of canals, instrument breakage, unaddressed anatomical complexities, can have a substantial impact on the outcome of endodontic treatment [4, 5]. The dentist must be aware of legal ramification of endodontic procedures and intraoperative errors to avoid legal consequences [6]. American Association of Endodontists (AAE) highlighted that general dentist has a legal and ethical responsibility to assess his skills and ability within the context of the specific case to guarantee the provision of timely and efficient care. Thus, cases that surpass the dentist's comfort level or skill proficiency should be referred to an endodontic specialist who possesses the necessary skills and experience to manage the case with minimum risks of endodontic iatrogenia [3]. The dislodgement of endodontic instruments can impede access to the root's apical region and hinder the disinfection procedure. This obstructs the effective cleaning and removal of debris from the canal located beyond the separated fragment, potentially compromising the success of the treatment [7]. Ledge is created when the dentist can no longer negotiate the working length and lost the original pathway of the canal. Ledge formation is an endodontic iatrogenia that can lead to apical transportation or zipping [8].

Various research groups reported that a high frequency of endodontic iatrogenia were produced by undergraduate students due to insufficient experience [9, 10, 11]. A retrospective study identified endodontic iatrogenic errors in 22.1% of all teeth that underwent treatment in the undergraduate clinics, with underfilling the most prevalent iatrogenic error (8.4%), followed by ledge formation at 4.2%. Also, molar teeth exhibited the highest frequency of errors, with the mesio-buccal roots of maxillary molars associated to the highest percentage of errors. Iatrogenic errors were associated significantly with the complexity of case, but it was not found any significant correlation between academic year and case difficulty, academic year and types of iatrogenic errors, root type and iatrogenic errors. The only significant association was found between tooth type and iatrogenic errors [12]. The frequency of intraoperative errors in a group of dental students was 31.1% with most prevalent underfilling (49.9%), followed by overfilling (24.1%), voids (12.6%), broken instruments (9.2%), apical perforation (2.3%), and root canal transportation (2.3%). Lower molars (43.1%) and upper incisors (19.2%) were the dental groups with the highest and lowest rates of iatrogenic errors [13]. One study reported an 1,83% overall incidence of instrument fracture during root canal preparation by postgraduate students. The prevalence of fractured stainless steel hand instruments was 0.55%, while that of rotary nickel-titanium instruments was 1.33%. Endodontic instruments fractured more frequently in the apical third of canals (52.5%) compared to the coronal (12.5%) and middle (27.5%) thirds. The same research group investigated the rate of retrieving or bypassing fractured instruments. The success rates were highest in the coronal (100%) and middle (45.4%) thirds, while the apical third exhibited a lower success rate of 37.5%. The frequency of instrument fractures was higher in cases involving retreatment in comparison to initial therapy cases [14]. Ledge formation and apical transportation are one of the most frequent endodontic iatrogenia reported in a group of dentistry students [8]. The prevalence of ledges was 6.54% of root canals, while zip was detected in 0.75% of root canals in a study assessing the accuracy of endodontic treatments in dentistry students [11].

The optimal management of endodontic iatrogenia is required as success rate of non-surgical retreatment is only 70,9% at 2-4 years, while surgical retreatment reach 77,8% success rate at same follow-up interval (71,8% at 4-6 years) [15].

Clinicians must possess a comprehensive understanding of the causes, prevention strategies, and reliable corrective measures for each of these endodontic complications [4]. Furthermore, it is crucial for clinicians to grasp how a specific complication can influence the prognosis of treatment, recognizing that this assessment can vary from case to case. There are clinical cases where a complication may have minimal repercussions on the treatment's overall success, while in other cases, same endodontic iatrogenia could severely compromise the treatment's outcome [4].

The prevention and management of endodontic iatrogenia requires a standardised approach for effective long-term outcome.

2. Prevention and Risk Management:

Understanding the clinical variables that dictate prognosis is of paramount importance. This knowledge aids in selecting the appropriate course of action and ensures that patients receive accurate information regarding the potential consequences of their treatment [4].

Before any endodontic treatment, dentist must consider preventive measures to reduce the risk of iatrogenic complications. Proper training and continuing education can help to minimize errors and endodontic iatrogenia. Complex cases that require experience and advanced techniques include teeth with severely curved roots, double curvature, calcified canals, C-shaped canals. These cases must be considered for referral to endontic specialists [12].

The risk management is based on documentation for legat and ethical reasons. The documentation include detailed records of the iatrogenic incident, treatment procedures, and patient communication. Also, dentist must educate the patient about post-treatment care, pain, and the required follow-up appointments while patients must apply proper oral hygiene practices to support healing. Dentist must consider ethical principles such as patient autonomy, beneficence, and non-maleficence throughout the period of endodontic iatrogenia management.

It's crucial to recognize that various patient factors can potentially add complexity to the treatment process. These factors encompass medical complications, challenges related to anesthesia, behavioral management issues, restricted mouth opening, and urgent treatment requirements. Moreover, one should also take into account past endodontic procedures, a history of dental trauma, and concurrent periodontic-endodontic conditions as additional elements of consideration [3].

Effective treatment planning serves a dual purpose. Firstly, it aids the practitioner in circumventing procedural errors such as overlooking canals, excessive dentin removal, perforations, ledges, instrument separation, or over/underfilling of the canal space. Secondly, it enables the dentist to make case selections judiciously, taking into account their experience, skill proficiency, and personal comfort level [3].

For effective prevention and risk management of endodontic iatrogenia AAE introduced a case complexity assessment form with the goal to allow general dentists and students in managing endodontic treatment in relation to their skill levels while referring challenging cases to endodontic specialists. This case complexity assessment form divides cases in three categories: minimal difficulty, moderate difficulty, high difficulty. Factors related to fractured endodontic instruments include the type of tooth and canal, the type and length of fractured segments, the location of instrument fracture, and the subsequent management approach [14]. Cases of minimal difficulty include teeth with no aparrent root canal curvature and normal diameter of root canals. Cases of moderate difficulty include teeth with no aparrent root canal curvature and normal diameter of root canals but with moderate inclination or covered by prosthetic crowns, or teeth with moderate curvature. Cases of high difficulty include teeth exhibiting multiple factors specific to moderate difficulty cases, teeth with calcified root canals, or teeth with various root canal curvatures such as severely curved roots, double curvature, C-shaped canals. For example, The presence of an S-shaped curve categorize the teeth as high difficult case due to the elevated risk of encountering obstructions or instrument separation within the canal. Furthermore, achieving effective canal space obturation becomes more intricate. In high difficult cases, ensuring a predictable treatment outcome poses a formidable challenge, even for a highly seasoned practitioner with a history of successful results [AAE et al, 2010]. The prevention of ledge consists of extension of the access cavity to allow easy access to the root canals, precurving and not forcing instruments, NiTi files instrumentarium, passive step-back and balanced force techniques, and instrumenting the canal to its full length will all help to prevent ledge formation [16].

AAE assessed the occurrence of iatrogenic complications subsequent to the use of this case complexity assessment form and revealed a significant correlation between the incidence of iatrogenic errors and the assessed case complexity. The AAE's tool of case complexity assessment plays a crucial role in determining the difficulty level of endodontic treatments while adhering to the recommendations provided by the AAE proved to be a significantly effective approach for reducing the risk of iatrogenic errors in endodontic procedures [12]. Dentists must recognize various medical conditions that could potentially complicate endodontic procedures enabling to prevent potential medical emergencies during treatment. Also, taking into account factors like anxiety, restricted mouth opening, or a heightened gag reflex empowers the dentist to prevent situations that could lead to iatrogenic errors [3].

Static and dynamic guided endodontics techniques are recommended to prevent endodontic iatrogenia. Static guided endodontics technique involves the creation of three-dimensional (3D) printed templates using cone-beam computed tomography (CBCT) images, surface scans, and virtual imaging software [17, 18]. A systematic review of static guided endodontics has determined that it is a clinical procedure enabling secure, precise, and consistent navigation of sclerosed canals while minimizing inadvertent damage during periradicular surgery [18]. The dynamic navigation system (DNS) represents a computer-aided guided technology initially designed for precise implant placement [19]. DNS provides real-time guidance to the clinician regarding the drill path as it progresses during treatment [20]. DNS consists of multiple cameras and motion tracking devices attached to both the dental handpiece and the patient, continuously comparing the actual path being created with the planned drill path using specialized software based on CBCT images of the affected teeth [21]. DNS was applied in endodontics to reduce the risk of errors during treatment of obliterated root canals. Difficult clinical scenarios such as cases involving pulp canal obliteration, conservative access preparation, endodontic retreatment, and microsurgery can be effectively addressed with lower chances of errors and in a more time-efficient manner through the application of Dynamic Navigation Systems [22]. The use of DNS in negotiation of the calcified canals was associated to success rates from 100% [20, 22] to 95%-99% [20, 23], and 90% -95% [21, 25]. The errors were misaligned or off-target drilling [21], unsuccessful canal location due to perforation [23] and gouging [26]. The factors relatic to systematic errors of DNS can be instability in jaw tracker positioning during treatment, interruptions in real-time tracking when adjusting the drill path, or incomplete mapping of reference points [20, 24]. It were also reported non-systematic errors such as unintentional mistakes arising from image acquisition or CBCT artifacts [20, 24]. DNS demonstrated superior accuracy, efficiency, precision, and reliability when compared with the freehand negotiation of calcified canals [24, 26]. Four systems (Navident, X-guide, ImplaNav, and DENACAM) were highlighted in the literature, but further studies are requested to compare their efficacy [22].

3. Management of endodontic iatrogenia

Steps in the management of endodontic iatrogenia are as follows:

1.Assessment and Diagnosis:

The first stage include the assessment of the patient's symptoms, clinical history, and paraclinical images (radiographic examen, CBCT). The analysis of data supplied by these investigations will allow dentist to give the diagnostic of endodontic iatrogenia. Endodontic iatrogenia are detected most frequently from the intra-operative or immediate post-operative digital radiographs. Some studies did not found any significant difference in various imaging techniques' ability to detect different categories of iatrogenic errors [27], while other report better diagnostic accuracy of digital periapical radiography when compared to CBCT technique in detecting separated instruments in root canals [28].

2.Communication with patient:

Dentist must explain to patient the diagnostic, clinical situation and potential complications as well as the treatment options, risks, and benefits, ensuring the patient's informed consent. Also, if case is complex or associated with challenging complications, the dentist must referr patient to an endodontic specialist or oral surgeon (if surgical management is required).

3. Immediate Management:

In cases of instruments fractures, clinical experience and a comprehensive understanding of influencing factors influence dentist' ability to make a well-informed decision Combination of ultrasonic techniques and dental operating microscopes is significantly more effective in the removal of separated instruments when compared with more randomized techniques [29]. However, relying solely on a single radiographic measurement technique is insufficient for accurately assessing root canal anatomy, case complexity, and the likelihood of successful removal before attempting instrument retrieval using a periapical radiograph [30]. Ultrasonic energy application under the dental operating microscope is recommmended for retrieval of fractured instruments in complex cases [31, 32, 33]. The choice of definitive management should be grounded in a comprehensive understanding of the success rates associated with each treatment option, weighed against the potential risks linked to either removing or retaining the fractured file [34, 35]. The success of instrument removal is significantly influenced by the fragment's position relative to the canal curvature, the angle of canal access, and the Schneider angle. The highest likelihood of failure in removal of fractured instruments was reported when the canal access angle exceeded 20^0 and the Schneider angle exceeded 40^0 [30]. While the incorporation of contemporary techniques into endodontic practice has enhanced the clinician's capacity to extract fractured files, it's important to note that removal may not always be a feasible or advisable course of action [36, 37]. The success rate in cases with fractured NiTi rotary files is between 61% and 100% in relation to canal curvature (higher in moderate curvature) and type of fractured file [38, 39]. Traditional conservative management typically involves one of the following: removal or bypassing of the separated instrument fragment or filling the root canal system up to the coronal level of the fragment. Alternatively, surgical intervention represents an alternative approach. These approaches are subject to various influencing factors and may carry potential complications. Decision-making regarding management should take into account the following considerations: the constraints posed by the root canal's ability to accommodate the fragment; the stage of root canal preparation at which the instrument became separated; the clinician's level of expertise; the available tools and equipment; the potential complications associated with the chosen treatment approach; the strategic importance of the affected tooth in relation to the presence or absence of periapical pathologies [40].

In pulp floor or lateral root canal perforations, the location and size of perforation must decide the proper approach. For minor perforations, repair may be possible during the initial treatment session by using materials like MTA (Mineral Trioxide Aggregate) or bioceramic materials to seal the perforation. A series of case reports highlight the long-term success of various MTA-based commercial products in reparation of iatrogenic furcal or mid-root perforations. It was reported, at follow-up between 2-7 years, the absence of any clinical indications or symptoms, regeneration of alveolar bone and a reduction in the periodontal space [41-44]. A resorbable collagen matrix was proposed to recreate the external contour of the root and simplifies the application of MTA [45]. When various materials used for repair of large iatrogenic perforations MTA leaked significantly less than glass ionomer cements and composite resins [46]. A comparison between various brands of MTA-based materials found similar clinical performance in repairing furcation perforations at 24- and 72-hour follow-up [47]. MTA is considered gold standard in repair of furcal perforations due to more favorable cost, availability, and similar outcome when compared with bioceramic-based material, while zirconia-reinforced glass ionomer cement has significantly more microleakage when compared with MTA-based material [48]. Operating microscope is recommended in the diagnosis, prognosis, and non-surgical management of iatrogenic perforation [49, 50]. The use of operative microscope improved the quality of iatrogenic cervical perforations sealed with glassionomer cement [51]. However, in complex cases, the patient must be referred to a specialist able to perform a surgical approach. In lateral root perforations, when area of perforation cannot be reached from the access cavity due to the angulation and excessive bleeding, surgical intervention is preferred, and after the root canal is filled, the perforation site can be sealed with MTA [52].

The immediate management of ledging can be performed by using specialized files designed to bypass the ledge and gradually advance towards the apex. When a ledhe has occured dentist must use a small file with a distinct curve at the tip with a slight rotation motion of the file combined with a "picking" motion to support the advancement of the instrument towards apex [16]. Advanced additive manufacturing technologies, in conjunction with semi-automated root canal segmentation, can be employed to replicate and improve the planification and management of ledges. The canal was isolated, and segmentation was carried out, including the other tooth structures. Based on CBCT images, a three-dimensional digital model of the canal's internal structures can be created using a segmentation software, and thus enabling the design and additive manufacturing of a mock-up. This mock-up represents a preclinical guide for simulating the procedure, pre-bending the file, and managing the canal effectively. One study reported that technique using virtual modeling from CBCT data post-ledge formation is a successful and rapid approach in the management of tooth with ledges [53]. When it is required, dentist must consider guided bypass techniques or removal of the ledge.

When intra-operative overfilling with obturation materials occurs, dentist must carefully remove the excess material from the canal space and then evaluate the possibilities to re-obturate the root canals or sealing the access cavity. Literature data on overfilling consists mostly of case reports exposing management of overfilling of root canal sealer and gutta-percha accidentally occurred [53] or overfilling associated to perforating external root resorption [54]. It was demonstrated the relation between three-dimensional seal established at the apical level, healing and gradual absorption of the extruded materials and the absence of any adverse impact on the long-term success of root canal treatment [53]. In cases associated to external root resorption non-surgical orthograde retreatment and obturation of resorped area with Biodentine lead to successful long-term outcome [54].

4. Monitorisation of healing

Dentist will use clinical examinations and follow-up radiographs to monitor the progress of the patient's healing. If the progression of healing processes is not occurring as expected, dentist will make adjustments to the treatment plan. Dentists should schedule the restorative appointment within one month after completing the endodontic treatment. For instance, if there are plans for a buildup and crown to follow the endodontic therapy, it is advisable to coordinate this scheduling with the referring dentist in advance. Thud it will be avoided extended delays between the end of the endodontic treatment and the placement of the final restoration considering that prolonged delays in final restoration placement can result in coronal microleakage and delayed healing [3]. AAE recommend to provide the patients with a comprehensive report that should include both pre- and post-treatment radiographs, as well as a clear assessment of the prognosis and any potential additional treatment requirements [3].

4. Conclusions.

Clinicians must possess a comprehensive understanding of the causes, prevention strategies, and reliable corrective measures for specific endodontic iatrogenia. Endodontic iatrogenia can be prevented by the use of AAE's assessment tool (dividing cases in low, moderate, high difficulty), operator microscope, static/dynamic guided endodontics systems. Endodontic iatrogenia must be managed by individualised therapeutic approach using effective instrumentarium and biomaterials for positive long-term outcomes. Professional development of general dentists and endodontic specialists is a key component of ensuring optimal patient outcomes in immediate and long-term management of endodontics iatrogenia. Interdisciplinary collaboration of general dentist with specialists (endodontic specialist, oral surgeon) can be required in complex cases.

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