Guided Endodontic Surgery

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Endodontic surgery has evolved over the past. The use of state-of-the-art guided endodontic surgical procedures produces a predictable outcome in the healing of lesions of endodontic origin. Surgical-guided endodontics is a relatively new area of study that is still maturing. It has many applications such as root canal access and localization, microsurgical endodontics, endodontic retreatment, and glass fiber post removal. Additionally, it does not matter how experienced the operator is; the procedure can be completed for the patient in less time and provides greater accuracy and safety than conventional endodontics.

Keywords: endodontic microsurgery ; guided surgical endodontics ; cone-beam computed tomography (CBCT)

1. Introduction

Traumatic injuries can result in increased dentin formation which leads to pulp obliteration (PO). This is due to calcification of the canal; however, it is not typically a sign of pulp damage. The other possible pulp response to injury is calcific metamorphosis, which manifests as a fast accumulation of firm tissue in the pulp region [1][2]. If a substantial amount of mineralized tissue has been deposited, the pulp space may completely disappear on radiographs, yet the histological sections may show some pulp tissue. Pulp obliteration can range from complete, where the pulp chamber and root ducts are indistinguishable, to partial, where the pulp chamber is still visible but the root canals are noticeably thin but still visible [3]. Inflammation of the pulp is a healing response that reveals the tooth's ability to repair, whereas the death of the pulp is pulp necrosis (PN). This may result in damage to the supporting periodontal tissues which may become infected via the dentinal tubules [4]. There is evidence that PN is common among teeth that have been damaged by trauma [3][5]. The best treatment option for these teeth is unclear. Several publications have argued that PO is due to the increased likelihood of PN following trauma or therapeutic procedures like orthodontics and restorative procedures [6]. Nonetheless, this standard is already being disregarded. Endodontic treatment should be delayed until either clinical symptoms appear or periapical tissues are involved [7]. However, these teeth require close clinical and radiographic observation. The endodontic treatment of PO teeth can raise concerns at any time [8]. When employing aids such as magnifying glasses, microscopes, or cone beam computed tomography (CBCT) to guide treatment, the operator, especially a novice, may find it difficult to grasp the CBCT visuals, build a mental guide, and simultaneously conduct the therapy. In response to these challenges, the discipline of guided endodontics (GE) emerged. Guided endodontics is founded on digitally planning endodontic therapy. Root canal perforations and other iatrogenic complications can be avoided with the use of GE procedures [9][10].

In 2016, an innovative method utilizing 3D-printed guides or splints, previously utilized in implant procedures, was introduced to endodontics. The effectiveness of these techniques for root canal access was originally studied by researchers and positive findings were reported [11][12]. The next year, the first case report describing the successful use of this technique to treat teeth with PO was published [13]. The integration of GE (a printed surgical guide) with CBCT images represents a novel method for achieving root tip access in surgical endodontics. In this way, the surgeon is able to make more exact incisions in the gingiva and bone, remove roots with greater accuracy, and facilitate more rapid healing following the operation. Less time is needed for this type of treatment compared to improvisational methods [14][15].

These days, endodontic procedures can be carried out using either static (SGE) or dynamic guidance (DGE). The upper or lower arch is scanned using a CBCT during SGE. When the two pictures are superimposed in software, a template can be made to go over the desired tooth (and some adjacent teeth). This will be used as a template for a drill hole of the right size and orientation to break through the calcified canal's walls. The root canal can then be accessed more precisely and steadily with a drill by fabricating cylindrical or sleeve-like guides. The inner, smaller cylinder is made of metal and fits snugly into the larger, outer cylinder. A stereolithography file is exported from the planning tool and used in a 3D printer to create the blueprints. A rubber dam is placed around the patient's teeth, and the guide is tried in to make sure it fits properly before the procedure continues. Once the calcified tissue is removed using the metal cylinder as a guide, root

canal therapy can proceed normally [16][17]. A stereo camera connected to an active navigation system can precisely time the entry and departure points when drilling into the pulp chamber or root canal. The operator can then watch their movements and fine-tune the position of the instruments [11][18][19][20].

2. Guided Endodontic Surgery

Openings used in endodontics: The initial stage in non-surgical root canal treatment is an endodontic access cavity, and much of the published research is based on this procedure. Four studies examined both minimally invasive and ultraconservative treatments [21][22][23][24][25]. Tooth structure can be conserved and instrument stress can be minimized by using a linear, ultra-conservative approach as described by Gambarini G et al. [21][26]. Access canals in endodontics are a contentious subject due to the variety of ways in which they can be defined and categorized [27][28][29]. While the traditional approach calls for removing the pulp chamber lid and going straight to the coronal third of the canals, the conservative and ultra-conservative approaches require entering through the central fossa and barely widening it to see where the canals are (in which the minimal access is made in the deepest center of the tooth). By keeping the incisions straight and the movements unimpeded when working in the coronal third, one can reduce the likelihood of perforations, false passages, and transferred canals [27][28]. This will help the operators in conserving the tooth structure. By using a conservative approach, the amount of healthy tooth structure that needs to be removed is minimized, which helps to preserve the overall strength and integrity of the tooth. Because of the trajectory produced by minimally invasive cavities, endodontic instruments must often flex in order to apply tension to the canal. Accidents caused by medical personnel, such as fractures and falls, are possible outcomes [14]. However, DGE prevents this by providing a direct, straight, and parallel path to the canal axis. In the researchers' opinion, this will provide conservative access to the root canal orifices and endodontic treatment can be performed conservatively. Despite being minimally invasive, conservative access cavities provide adequate access to the pulp chamber and root canals, which facilitates the efficient removal of infected or damaged tissue and the thorough cleaning and shaping of the canals. It has been shown that less tooth tissue is lost as compared to "standard access cavities". Even while research has shown that the fissure resistance of posterior teeth might vary based on the endodontic access method utilized, the resistance of anterior teeth is consistently high regardless of the approach taken. For teeth with intact marginal ridges, endodontic access has been shown in investigations to have no influence on tooth stiffness. Data collected by a dynamic guided navigation system were used by Simon GC et al. [30]. Instead of using drills to create multiple access cavities, CO_2 laser ablation was employed in both open surgery and minimally invasive surgery. It is possible to reduce contamination in the outer layers of soft or hard tissues by burning the contaminated tissues and toxins to a high degree using lasers. Hemostasis induction is also a useful technique for dealing with pulmonary resections [22]. However, it is important to remember that the heat produced by the laser heat might produce pulp hyperemia and that this can be avoided by eliminating the afflicted pulp tissue using hand equipment [31]. Laser-assisted pulpotomies had similar clinical and radiographic success rates as those of mineral trioxide aggregate and formocresol. Since the digital representation of the occlusal surface is provided by the dynamic navigation system, CBCT data are not required for laser surgery. The user can program the computer-controlled laser to automatically complete a predetermined access procedure. Due to its potential use in difficult situations with calcifications, guided endodontics may be useful for patients with atypical tooth morphologies that make conventional endodontic treatments difficult. While 3D splints have been mentioned in the treatment of dens invaginatus and dens evaginatus by several researchers, no studies have focused on this technique. Utilizing a non-invasive cavity preparation method, Jain SD et al. drilled at high speeds and used DGE to identify calcified canals. In cases when these canals were manually located, there was a higher incidence of perforations and tissue loss [32]. During SGE, the treatment time was reduced by switching from low-velocity to high-velocity drills and using 3D guides.

Detecting calcified canals: Extracting a small quantity of tooth tissue, and finishing the course of treatment in about the same length of time are all things that a non-specialist operator may be able to achieve just as well as an endodontic specialist, as shown in the study by Connert T et al. Because the access cavities created by GE, especially SGE, can only provide linear access, this treatment modality cannot be utilized on teeth that include curved canals or unusual shapes. Multiple guides for direct gonadectomized endodontics will need to be fabricated if a single tooth has more than one straight canal. In cases where many neighboring teeth, such as incisors, require root canal therapy, options such as a single guide with multiple accesses or a DGE treatment scheduled for a single appointment to complete all of the root canals can be considered. Teeth with PO and relatively straight or slightly curved apical third canals are suitable for root canal therapy. Fonseca WL used a combination of SGE/DGE to the extent possible, the traditional instrumentation of the curved region, and retrenching as photodynamic therapy. Therefore, it is recommended that further research should be conducted on a variety of problems. However, the overall understanding is that the use of guided endodontics allows for the operator to precisely control the instruments and navigate around the curves of the canal with minimal risk of

damaging the surrounding tissues. It can also reduce the risk of complications such as instrument fracture, perforation, or ledge formation in curved canals, as it allows for a more controlled and minimally invasive approach to treatment.

Apicoectomy and osteotomy are two particularly notable surgical options. The second most common GE operation after approximation is osteotomy [33]. Only one retrospective study provides long-term follow-up data on patients who underwent SGE [34]. However, the SGE procedure is not disclosed. More studies of patients who undergo either sort of GE are needed, but with longer follow-up durations. All the studies produced flaps analogous to those employed in clinical settings of endodontic microsurgery. Several studies have suggested avoiding the flap procedure when removing the masticatory palatal mucosa [35]. This novel approach to endodontic microsurgery may lessen the risk of complications and post-operative discomfort when apicoectomies on the palatal roots of maxillary molars are performed [36].

Glass fiber post removal: Taking apart the glass fiber post, extraction of a post and crown from a previously treated tooth is the third most common procedure while utilizing GE [37]. This is studied by Afram A et al. When other methods of removal have failed, ultrasonic tips are frequently used to remove fiberglass posts [38]. One risk is a punctured tooth [39]. Additionally, due to the similarity in the color of the post and the dentine, this procedure can cause some problems. After the post is removed, the radicular canal can be widened depending on the dentist's skill [32]. This is accomplished by removing extra dentine around the post. Because of these concerns, GE has been presented as a potential treatment option. Perez C et al. observed that the apical gutta-percha was reachable in 87.5 percent of treated teeth with SGE, with the remaining 12 percent being inaccessible due to root curvature. Notable as well is the fact that this models the artefacts inherent to CBCT pictures, which can make it more challenging to recover design and construction data. However, it fulfilled the requirement, and in a quicker way than either the UTC recommendations or the lonthingem drills. Laser post removal is just as effective as milling and microscopy but much faster. However, familiarity with the new set-up was necessary before the operator could get to work swiftly and easily. The use of guided endodontics can help accurately position the drill or bur for removing the post. This is particularly useful when dealing with a broken post or a post that is deeply embedded in the root canal, as it allows for precise removal without causing additional damage to the tooth. It can also help reduce the risk of damage to the tooth or surrounding tissues during post removal. However, it is important to note that the success of post removal ultimately depends on the skill and experience of the dentist performing the procedure. While guided endodontics can enhance the efficacy of post removal, it is not a substitute for proper training and experience in performing endodontic procedures.

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