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GUIDED ENDODONTICS

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RESUMEN

Este trabajo de fin de grado es el resultado de una búsqueda y síntesis bibliográfica realizada mediante bases de datos como Medline y Pubmed. Los artículos que han sido seleccionados sobre la endodoncia guiada son al máximo de 2016 teniendo en cuanta la novedad de las técnicas descritas y el numero des investigaciones hechas. Este trabajo permite descubrir cuales son los principios de estas nuevas técnicas de tratamientos, sus indicaciones, contraindicaciones, así como sus ventajas y limitaciones. Se encontró que las técnicas guiadas en dientes con conductos calcificados aportaban buenos resultados y una cierta seguridad con respecto a la dificultad que presentan estos conductos en sus localizaciones y instrumentaciones. Sobre los dientes que necesitaban cirugías tras el fracaso del tratamiento por vía ortograda, se encontró que las técnicas guiadas simplificaban la localización de los ápices y que facilitó el proceso postoperatorio de los pacientes y aumentaba las posibilidades de éxito del tratamiento. Se ha demostrado que las técnicas de endodoncia guiadas aparecen como más eficientes, más precisas, que consumen menos tiempo, son menos invasivas y dependen menos del operador que la técnica convencional a mano alzada. Además, en todos los artículos revisados, las técnicas convencionales de tratamiento de conducto y de cirugía apical no consiguieron tener los mismos resultados que las técnicas guiadas. La principal limitación que se encontró en técnicas guiadas es el coste adicional que necesitan en comparación con las técnicas convencionales. La eficacia de estas técnicas ha sido ampliamente demostrada a lo largo de este trabajo y parecen ser más eficaces y seguras que las técnicas convencionales. Sin embargo, concluimos que la novedad de las investigaciones y la falta de estudios en muestras más grandes, así como la no estandarización de los métodos de evaluación, no permiten establecer conclusiones definitivas.

ABSTRACT

This final degree thesis is the result of a bibliographic search and synthesis carried out using databases such as Medline and Pubmed. The articles that have been selected on guided endodontics are from 2016 at the latest, taking into account the novelty of the techniques described and the number of investigations carried out. This work allows to discover what are the principles of these new treatment techniques, their indications, contraindications, as well as their advantages and limitations. It was found that the guided techniques on teeth with calcified canals provided good results and a certain safety with respect to the difficulty that these canals present in their localization and instrumentation. Regarding teeth that required surgery after failure of orthograde treatment, it was found that guided techniques simplified the location of the apices and facilitated the postoperative process for the patients and increased the chances of successful treatment. Guided endodontic techniques have been shown to be more efficient, more accurate, less time consuming, less invasive and less operator-dependent than the conventional freehand technique. Moreover, in all the articles reviewed, conventional root canal and apical surgery techniques failed to achieve the same results as guided techniques. The main limitation found in guided techniques is the additional cost they require compared to conventional techniques. The efficacy of these techniques has been amply demonstrated throughout this work and they appear to be more effective and safer than conventional techniques. However, we conclude that the novelty of the investigations and the lack of studies on larger samples, as well as the non-standardization of the evaluation methods, do not allow definitive conclusions to be drawn.

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INTRODUCTION

The access cavity is one of the key step in root canal treatment (1). The correct opening of the pulp chamber offers a clear access to the canals and a correct debridement of all debris that could be present in the pulp chamber. It is well documented that the long-term triumph of endodontically treated teeth is one of the most challenging goal to achieve because of their decreased resistance to fractures. Traditional endodontic cavity (TEC) is the less conservative method and leads to the removal of sound tissues that is superior to the amount removed in minimally invasive cavity access. Enlarged preparation of cavity access enhance deformability of the tooth and thus making the endodontically treated tooth more prone to fracture (2). Lately, tooth structural integrity has been shown to be the main factor influencing on the tooth resistance so in order to keep as much tooth structure as possible, minimally invasive access cavities have emerged.

Endodontic treatments always conduct loss of tissues regardless of the type of access cavity (3). Not all teeth are equal facing such treatment. We can find different types of canal regarding their size, shape, path and some are easier and less risky to treat with conventional freehand method with the guarantee of successful treatment and a favourable prognosis. This is not the case of the pulp calcified canals (PCC) or pulp obliterated canals (PCO) (4). These canals are obstructed by the apposition of mineralized tissue as a result of carious lesion, trauma, orthodontic treatment (because of the blood supply disturbance they can provoke) or restorative treatment. PCC can be find as well in elderly patients as a result of the continuous formation of secondary dentine throughout life (4-5). These teeth do not necessarily require a root canal treatment as the calcification of the pulp can be seen as a form of healing after a trauma. However, in case of symptoms such as pulp necrosis or periapical pathology, the root canal treatment will be indicated.

Teeth presenting PCC have shown to be more complicated to treat because of the difficulty to locate the canal even with the use of optical microscope (6). In PCC cases, complications such as root perforation and canal deviation have been observed (7). In order to treat these cases, a new minimal invasive technique called “guided endodontic” has emerged recently. This technique is divided into two categories: static system and dynamic system.

The static system consists of guiding a drill trough the canal access cavity with a 3D-pressed template previously obtained thanks to the merging of both CBCT and intraoral digital scan. In comparison with the static system, the dynamic system delivers a real-time guiding over the treatment which allows the operator to evaluate if the previously digitally planned procedure is being followed correctly.

“Guided endodontic” techniques do not only include root canal treatment of PCC. The apical surgery is often the treatment of choice after the failing of root canal treatment. It consists on the resection of the apex of the tooth and the complete debridement of the infected periapical tissues by the mean of curettage (8). Among the factors influencing the success of a periapical surgery, the type of lesion, the material used to perform the retrograde obturation as well as the coronal restauration that will be placed have been noticed (9). Recently novel techniques appeared to make those treatments less invasive, less operator dependent, less time-consuming and more predictable. It has been demonstrated that the postoperative complications in apicectomy is greatly influenced by the extension of the osteotomy. The attainability of the apex can be challenging because of the thickness of the bone or anatomical structure making the surgery more complicated. So, “Guided endodontic surgery” has been proposed, it is performed by the mean of 3D-printed template that allows the operator to target exactly the area where to realize his osteotomy and thus minimize it being more conservative and less traumatizing for the patient (10). As for orthograde root canal treatment, guided endodontic surgery can be perform by the mean of a dynamic system which allow the operator to visualize in real-time if the treatment is going as planned prior to the procedure (11).

OBJECTIVES

The principal objective of this literature review is:

- Present static-guided endodontic techniques and dynamic-guided endodontic techniques.

The secondary objectives of this literature review are:

- Compare the new guided endodontic techniques with conventional freehand endodontic technique for the treatment of pulp calcified canal.
- Present the guided endodontic surgery and compare it with the conventional endodontic surgery.

MATERIALS AND METHOD

With the aim of achieving this review, several articles were selected using the platform PubMed and Medline. They were all referenced and cited thanks to the software Mendeley. The articles selected were chosen according to their date of publication: from 2016 to 2020.

The following key words were used to specify the selection: 3D-template, computer-aid endodontic, guided endodontics, dynamic guided endodontics, static guided endodontics and guided endodontic surgery.

Several clinical cases were picked in order to compare the results obtained and have a clinical point of view of these new methods.

RESULTS AND DISCUSSION

Static guided root canal treatment

As mentioned previously, the guided root canal treatment aims to treat the teeth with PCO. Over the last decades, it has been documented that the teeth presenting PCO could suffers complications when performing conventional free-hand root canal treatment. Based on Kvinnsland *et al.* (1989) 20% of the perforations were due to the difficulty to locate properly the canals in teeth with pulp obliterated canal (12). In another study conducted by Cvek *et al.* (1982) 20% of the failed treatment were done on incisors presenting calcified canals (13).

Guided endodontic treatment appears to be a good alternative option when curing obliterated canals. All the literatures available on this topic present guided access cavity as very accurate when comparing the cavity perform and the one previously planned virtually. In addition to being very accurate, no root perforation were mentioned when opting for guided endodontics access (13-15).

The accuracy of the guided access has been measured by superposing preoperative CBCT-scan and postoperative CBCT-scans taken once the access cavity was done. The different authors measured the deviation of the tip of the bur, deviation of the base of the bur, the deviation angle and finally the success rate. The study conducted by Buchgreitz *et al.* (2016) didn't provide other information than the deviation at the tip of the bur which was of 0.46mm (16). Regarding the study conducted by Zehnder *et al.* (2016), a mean angle deviation of 1.81° was found with a mean mesial/distal (MD) deviation a the tip of the bur of 0.29mm, buccal/oral (BO) of 0.47mm and apical/coronal (AC) of 0.17mm (15). For their part, Connert *et al.* (2017) registered lower values, a mean deviation angle of 1.59°, a mean MD deviation at the tip of the bur of 0.14mm, BO of 0.34 mm and AC of 0.12 mm (17). A 100% success rate were achieved in this study. An interesting fact given by the last two authors was that no statistical differences were found between the guided cavities done by two different operators which traduce the fact that the realization of the cavity was achievable and reproducible by two different practicians.

As a comparison with implant placement by the mean of 3D guide tooth supported, Schneider *et al.* (2009) found a mean deviation angle of 5.29° which is much higher than the one found in the different study for guided endodontic (18). Regarding the mean deviation at the apex of the implant, Tahmaseb *et al.* (2014) found a value of 1.39mm which is still higher than the ones found for guided access cavities (19).

In 2019, Connert *et al.* conducted an in vivo study with the aim of comparing the endodontic access cavity using conventional freehand technique and guided one. They studied the substance loss, the localization of the canal and the treatment duration. To achieve this study, they used 6 identical sets of superior and inferior jaw produced by the mean of 3D-printed incisors simulating the calcified root canals. The access cavities using both techniques were performed by 3 practicians with different experience (one of 9 years' experience specialist endodontist, one with 3 years' experience general dentist and one newly graduated). Each of the dentists participating had 8 teeth per technique and operator. The access cavities realized by both techniques were evaluated using a postoperative CBCT scans. The result obtained are shown in the following table:

	Canal location	Mean substance loss	Treatment duration
Conventional technique	41.7%	49.9 mm3	21.8 min
Guided endodontics	91.7%	9.8 mm3	11.3 min

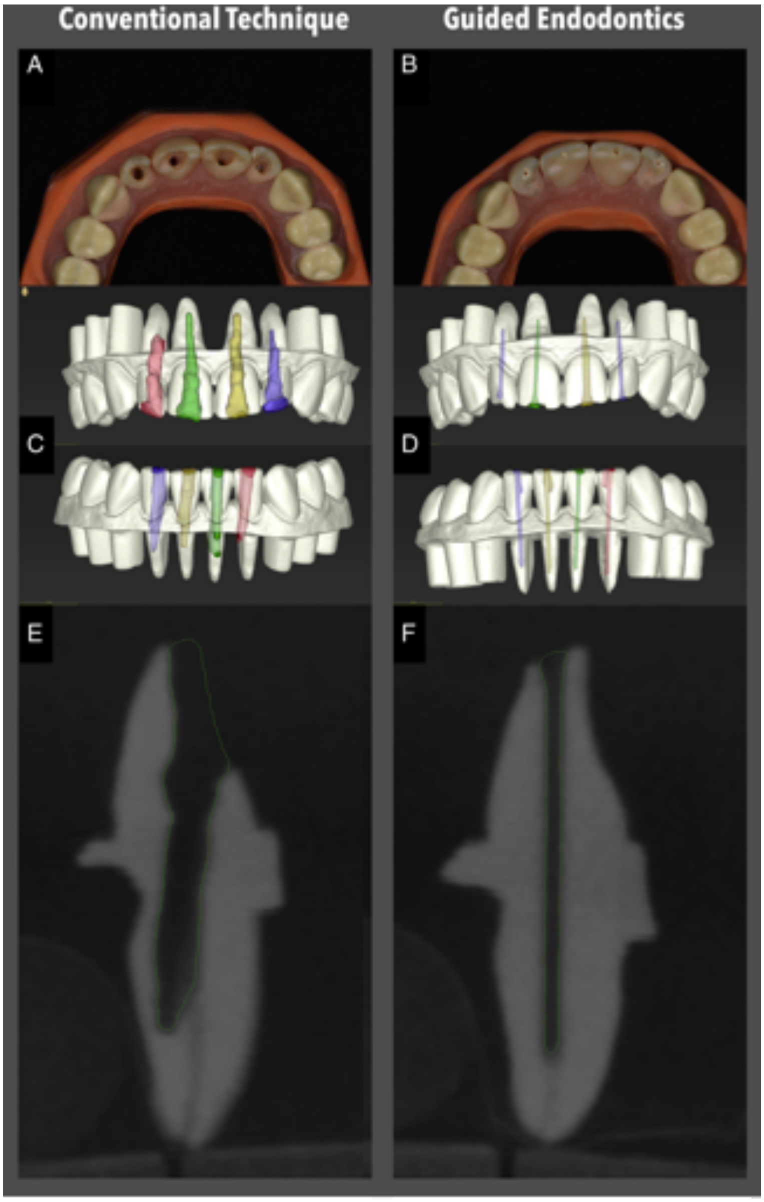

Figure 1. Issued from Connert et al (2019) study (20).
A and B: maxillary incisors after access cavity preparation. C and D: visualization of the access cavities in maxillary and mandibular incisors. E and F: postoperative CBCT scan showing the lower incisors in a sagittal plane.

Regarding the localization of the canal in the conventional technique, the newly graduate operator did not find any of the canals while the 3 years experienced dentist found 4 of the 8 canals and the specialist 6 of the 8 canals. With the guided technique, the unexperienced operator found 8 of the 8 canals while the other two found 7 of the 8 canals. This traduces clearly that the guided technique is not as experience dependent as the freehand conventional technique and that a freshly graduated dentist could be able to use this technique.

Even though guided endodontic is easier to perform in the anterior sector due to the accessibility of the site, it has also been performed in the posterior sector to solve cases presenting pulp calcified canal (20-21). Sônia T de O. Lara-Mendes, Camila de Freitas M. Barbosa, Caroline C. Santa-Rosa and Vinicius C. Machado have done a case report where guided endodontic has been chosen as treatment technique. The patient referred to the consult complaining about discomfort in the posterior region of the second quadrant. No pulp response to the vitality test has been recorded and the percussion was slightly positive. Extensive bone reabsorption was observed on the CBCT scan at the apex of the 27 and 28. Unfortunately, after trying the conventional technique, the operator failed to locate the palatal canal of the 27 and the distobuccal canal of the 28. Thus, a high-resolution CBCT scan were taken to be able to have a more detailed view of the periapical radiolucencies and of the anatomy of the canals. The palatal canal of the 27 and the distobuccal canal of the 28 were observable only in the apical and middle third. Given the situation, a guided endodontic approach was chosen.

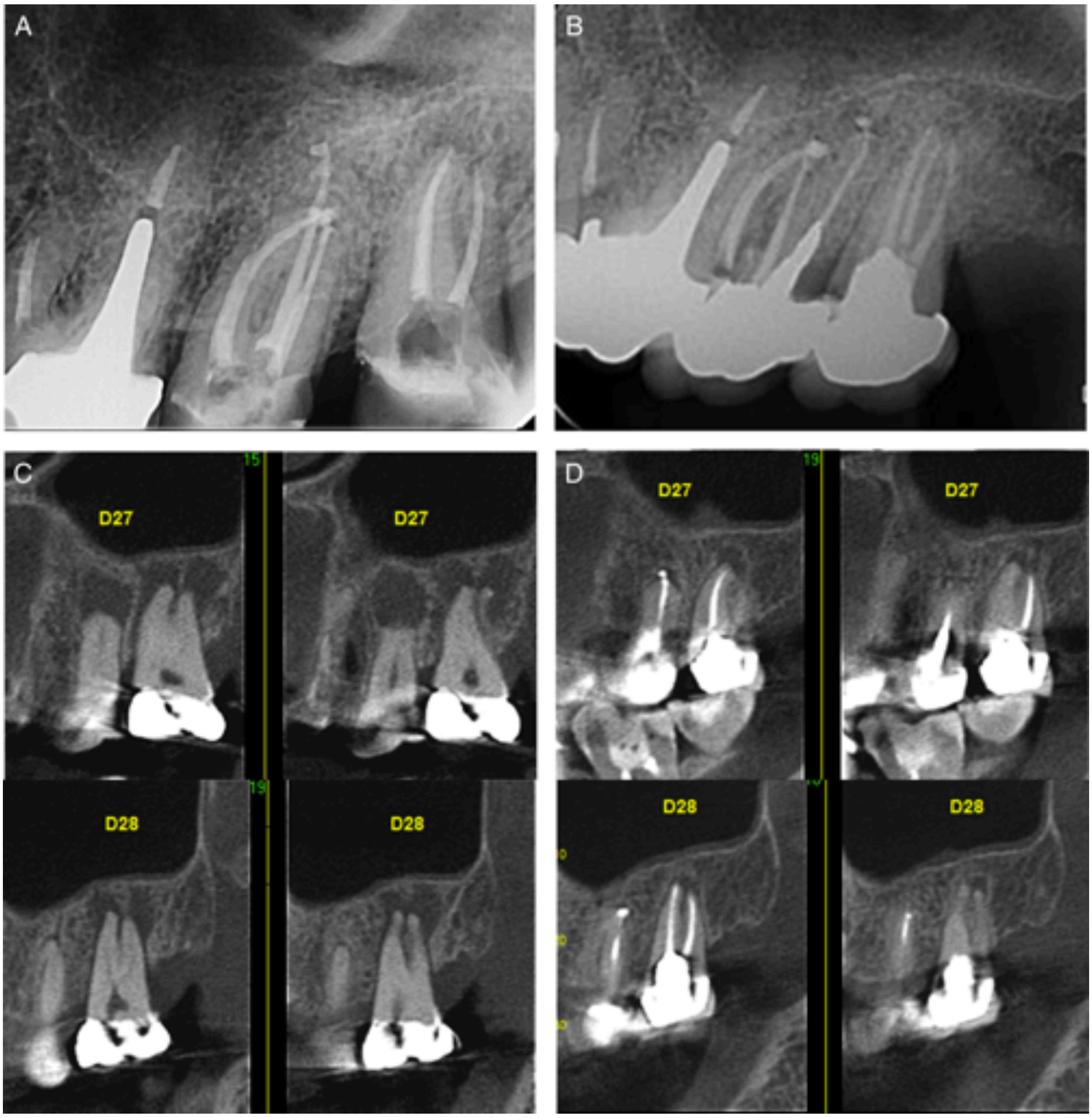

Figure 2. A: control x-ray at 3 months. B: control x-ray at 1 years. C: Preoperative CBCT scan. D: CBCT scan at 1 year (21).

The one-year control x-ray and CBCT scan showed a clear reduction of the periapical lesions and the patient presented negative response to percussion test nor symptoms such as pain. This case demonstrated clearly that guided endodontic procedure for root canal treatment is a suitable alternative when having difficulties locating canal.

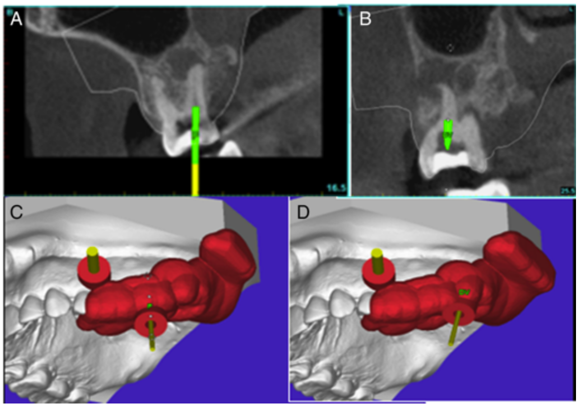

Figure 3. A and B: Virtual drill superimposed over the 27 and 28 thanks to the implant software Simplant.
C and D: Design of the virtual template by the mean of Simplant (21).

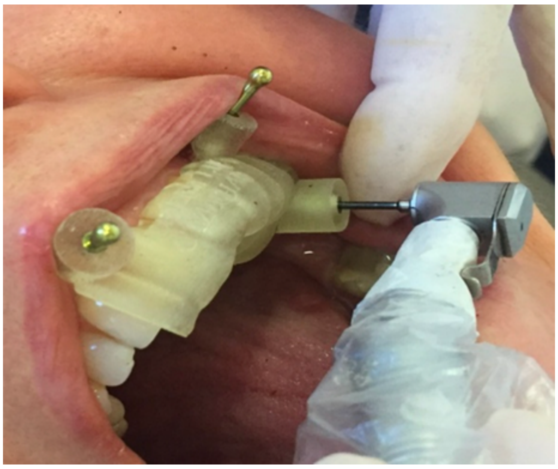

Figure 4. Access of the root canal by the mean of the 3D-printed guide (21).

Guided endodontic technique has also demonstrated its effectiveness in the succeed of case where perforation and/or deviation of the canal occurred using conventional technique (22). Iatrogenic accidents may occur during endodontic procedures. Anatomy of the tooth and its variations must be known in order to perform a successful endodontic treatment. Although, having this in mind does not guaranty succeed in the treatment. Among the complications that you can face when performing a root canal treatment, the deviation of the original path of the canal is common. This complication would lead to difficulties reaching the working length or even make it impossible. Thus, it would be traduced by a non-adequate instrumentation and obturation and thus compromising the treatment outcome. In pulp calcified canal, the appearance of deviation could be due to a defective preparation of the access cavity or to a wrong estimation of the path of the canal (23). Here is a case of a 15 requiring root canal treatment because of pulp necrosis and chronic periapical abscess. The initial access cavity preparation of the canal was performed by the mean of conventional technique which result in a deviation and perforation of the canal.

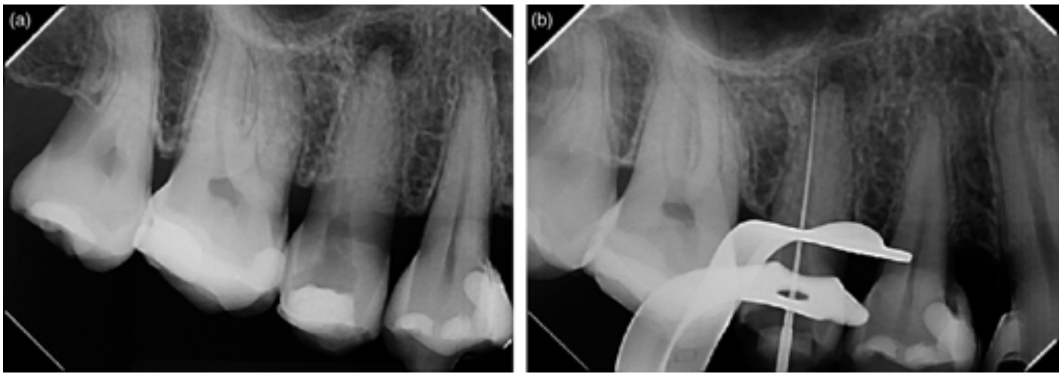

Figure 5. A: preoperative radiography B: Radiography of the 15 showing the perforation and deviation of the canal (22).

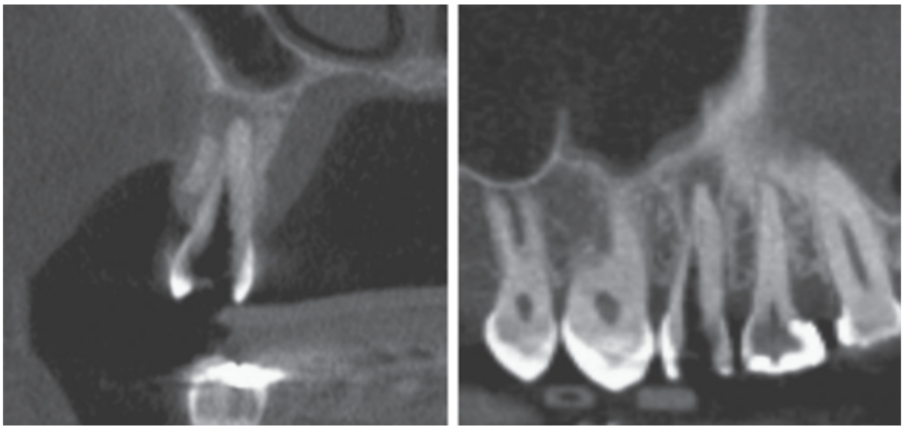

Figure 6. CBCT scan showing the deviation and perforation of the canal of the 15 (22).

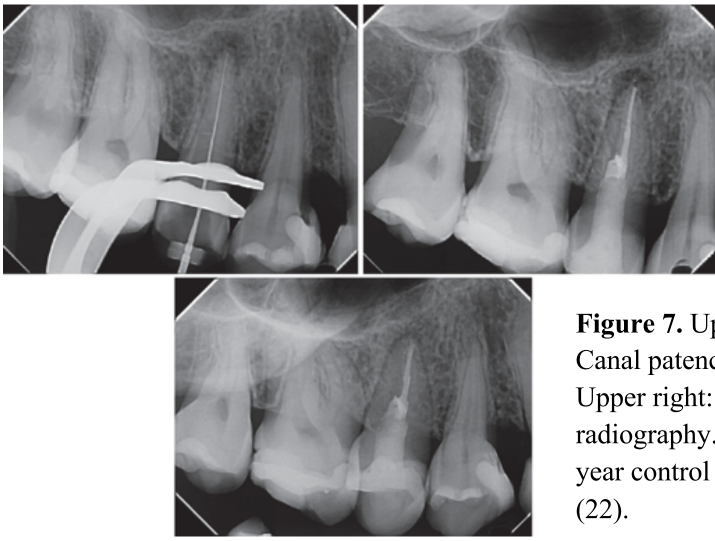

Figure 7. Upper left: Canal patency checking. Upper right: final radiography. Lower: One-year control radiography (22).

This case report displays that guided endodontic treatment is a reliable option to restore original path of the canal in case of deviation in PCC. It has been achievable to proceed to the cleaning, shaping of the canal all along it as well as repairing the wrong path done before.

The utilization of the CBCT scan in endodontic has changed over the years because of its utility when diagnosing periapical pathologies, approaching different complex tooth anatomy and detecting PCC or even defective restauration (24). Indeed, in 2015, the guidelines regarding the uses of CBCT imaging in endodontic have been updated by the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiography. CBCT scans is recommended in cases of calcified root canals to allow thy correct location because of the difficulties they present (25).

It has been stated by the authors that the success rate of the teeth with PCO presenting periapical periodontitis did not surpass 62.5% even though for the same cases it could go up to 89% when treated by endodontic specialist (12,26-27). Facing radiographic signs of PCO and periapical periodontitis, guided endodontic technique could be chosen for a more foreseeable access of the apical third of the canal. This technique is of great interest for the less experienced operators since it eliminates the need of microscope and conserves as much tooth structure as possible (15-17,26,28).

One of the factor related to an increased or decreased risk of fracture is the coronal access depending on whether or not it is of great extension (29). In fact, the coronal structure loss due to the access cavity will conditionate the need of posts to support the final restoration of the treated tooth. Teeth with great access cavity extension will require posts while the one treated with conservative access won’t (30-31).

Static guided endodontic presents limitations. This technique can only be used in teeth with straight canals or only in the straight part of curved roots. Furthermore, the bur used could generate microcracks on the dentine as it generates more heat than conventional files. This increased temperature could damage the periodontal ligament or adjacent bone (32). Also, another drawback of this technique is the need of a CBCT scan which increased the radiation dose of the patient even though it is completely justified (5).

Dynamic guided root canal treatment

Static guided endodontic by mean of template presents some limitations. It doesn't allow much freedom once the guide is manufactured, its dimensions and specificities cannot be changed easily (size, depth, angulation) (33). Additional costs for the manufacturing of the guide and additional time required to planning may as well be seen as drawbacks. Moreover, the space required for the placement of the static template is as well a limitation in the posterior sector of the mouth as well as in patient with small mouth opening (34).

As for the static guide, the dynamic navigation system comes from the implantology field. In implantology, the virtual implant position is set thanks to a computer software and the preoperative CBCT scan. Then, real-time tracking system provides the information related to the implant place meanwhile doing the surgery which guides the operator and the exact position of the handpiece is known (34). In the recent literature, it has been reported that it is equal or superior in term of accuracy compared to other computer-assisted techniques (32-34). The precision of the dynamic system allows a safer practice as it decreases the risk wrong paths, perforation or the non-location of the canal. In contrast with the static system, the dynamic one allows some freedom to the practician making him able to adapt to each clinical situation that were not possible to plan or anticipate (34). As a new technique, it has not been a lot investigated. It has been described in a study conducted by Bun San Chong, Manpreet Dhesi and Jimmy Makdissi in 2019. In order to conduct their study, they selected human extracted teeth with intact crowns and roots. Light body silicone was introduced in each teeth's canals to simulate PCC. Then, all the teeth were set into 3 different casts reproducing a dental arch. Preoperative CBCT scan and periapical radiographies were taken. They performed conservative guided access cavities and all the expected canals were found in 26 teeth. They met difficulties in the location of the canals in 3 teeth: molars only. In fact, only the palatal canal was located in the 17 and 27, in the 26, only the mesiobuccal and palatal canals were located successfully. Unfortunately, the access preparation of the distobuccal canal was not aligned correctly. Given the results obtained, they demonstrated the potential of this new technique.

Guided endodontics, in surgical and non-surgical approaches, have been more studied using static guides. However, the dynamic navigation system have been investigated in the recent literature and shown as accurate leading to successful results (38). As for the static system, they are several needs for the dynamic guided endodontics. One mandatory tool for this treatment option is the CBCT scan. The costs associated with this technique are not negligeable and could figure as a major drawback as it implies investment including disposable material. Both dynamic and static guided technique have advantages and disadvantages over each other. One of the advantages of the static guide is that it doesn't allow the operator to deviate from the planned path. It is of great interest when the practician is not experienced. However, it can also be seen as a drawback as it implies a limitation regarding the freedom of changing/adjusting the planned path when facing a clinical situation slightly different than the one expected. Regarding the advantages of the dynamic guided system over the static one, we can find several. It is possible to achieve the treatment in one and only appointment, it is safer and has an increased predictability as it is checked in real time, the planning of the operation is easier and faster, the irrigation is not impeded by any template and thus reducing the risk of structure damages due to overheating. Finally the dynamic system is usable in sites where the access is limited due to a reduced interocclusal space or interdental space where a 3D-printed template wouldn't fit (39).

Concerning the inherent errors that can happen in the dynamic systems, we can face three types: machine related, patient or tooth-related and operator related. The machine related errors are related with an incorrect installation of one or more of the components needed to perform the procedure. For instance, an instable jaw splint could lead to further errors. However, it could be checked and fixed prior to the treatment. Tooth or patient-related errors could be presented as the one that affect the planning of the procedure. The planning of the procedure could be affected by an inadequate pre-operative CBCT scan affected by previous restorations present on the tooth/teeth to treat. The state of the tooth is also a factor that could affect the accuracy of the treatment (39). Even though this technique is guided, the clinician has a great part in its realization. In. fact, the dentist controls the handpiece without any physical guide which make this technique considered as freehand by several authors. This could lead to intra operator's variability in the execution of the procedure. It could imply mistakes by not following the original plan and thus cause deviation. The operator experience is of a greater importance in dynamic guiding system than in static system (39). The principal downside of the dynamic system is the need to look on the system display to know what you are doing and so not having a direct vision of the operating field. Another downside of this system is the setup that it requires. It requires quite a lot of material, from the bulky handpiece to the splint or even the monitor displaying all the information. All of this presenting an additional cost to the treatment may restrict its use.

Guided static endodontic surgery

Endodontic surgery is indicated in teeth presenting apical periodontitis when previous non-surgical root canal treatment has failed. It is documented that conventional apical surgery has a quite low success, going from 43.5% to 74%. However, with the modernization of the techniques, the eruption of new materials, the microscope, the success rates has increased ranging from 88.9% up to 100% (40). As a new technique, guided endodontic surgery technique has also been investigated by some authors over the past years. As for the guided orthograde root canal treatment, static 3D-printed template has been used. The surgical stent is obtained after merging both intra-oral scan and pre-operative CBCT scan through an implant planning software just like for the static guided root canal treatment. They can be bone-, mucosa-, or tooth-supported (39-42).

The success of the endodontic surgery is largely influenced by several factors including the type of lesion to be treated, the filling material as well as the restauration of the tooth (45). Some authors stated that the position of the tooth was a factor influencing the prognosis of the treatment. In fact, the anatomy of cortical bone and the presence of adjacent anatomical structures such as nerves, sinus or foramen contributes to the outcome of the procedures as it can make the treatment even more complicated to perform and engender complications (46).

Traditional method implies important bone resection and thus augmented postoperative pain, deferred healing or even nerve injury. The use of conventional bur also can be at the origin of the complications and the damages caused to the adjacent structures. Some authors have used alternative material to perform their osteotomy in guided surgery by mean of trephine burs with a stop that block the bur when reaching the desired length or even piezo-surgical devices that do not hurt the nerves, the vessels or the mucosa (10,42).

The guided static technique consists in defining the area where to perform the osteotomy as describe by the authors in the recent years. Some created a "window' in their guide to delimitate the area where to do the osteotomy and some as for the guided root canal place a sleeve in the guided to have the correct angulation and go directly to the apex of the tooth to treat and being minimally invasive (9-10,42).

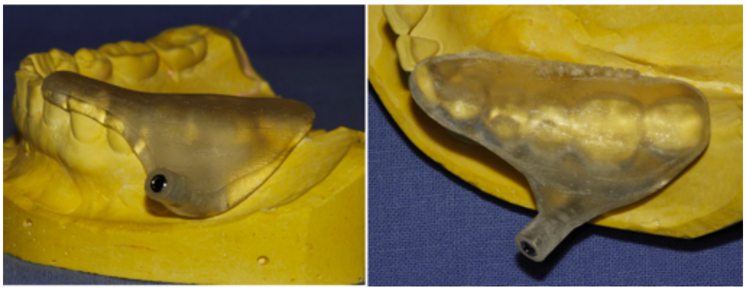

Figure 8. Example of a surgical guide of a cast with a sleeve to guide the bur to the apex of the tooth to treat (9).

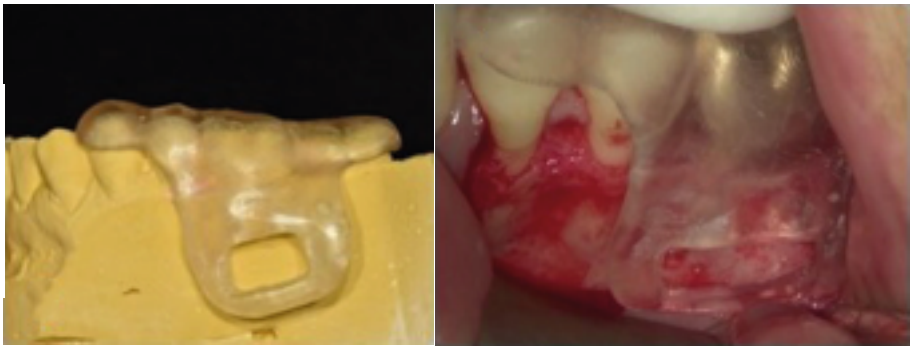

Figure 9. Example of a surgical guide with a "bone window" on a cast and the operation site (10).

Thanks to the use of surgical guide, the extension of the osteotomy is delimited and thus decreased. This allows lower post-operative complications. Depending on the type of guide use, it can be possible to keep the removed cortical bone to later put it back in place as autogenous graft which would promote an early cicatrisation (10).

As any digital planning, it requires time before the procedure to plan the surgery but then it allows the practician to then go straight to the apex of the tooth and avoiding him to waste time looking for the apex and potentially damage adjacent structures (e.g. Apex of another tooth). It is documented that the extent of the swelling post-operative is influenced by the duration of the procedure so the use of guide is relevant as it decrease the operating time and thus decrease the post-operative inconvenience of the patient (43-44).

The use of 3D-printed guide is very useful when facing complex cases where adjacent structures can be compromised. It permits to the operator to avoid the critical anatomical landmarks and thus avoid iatrogenic damages.

This technique to perform apical surgery appears to be safer as it is less operator dependent, it reduces the operating time and is more accurate when it comes to "find" the apex of the root. Bone "window technique" using piezo-electric devices and trephine bur technique reaching the apex directly have shown to be effective according to the author. One of the main advantage of the custom trephine burs introduced by M. Antal *et al.* over the conventional bone trephine burs is that they have a stop which hinder the risk of overpenetration of the bur (10,41-42).

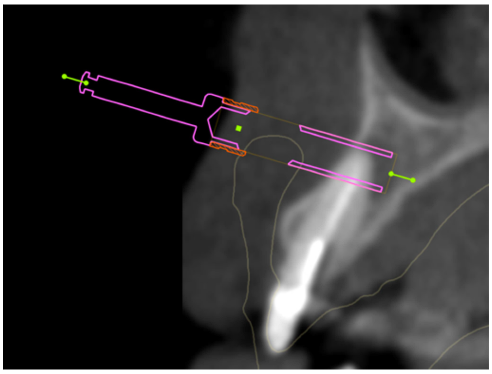

Figure 10. Virtual planning of apical surgery performed with custom trephine bur (41).

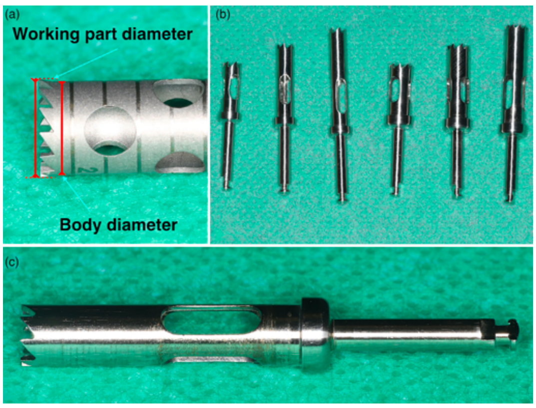

Figure 11. a) conventional trephine bur.
b/c) custom trephine burs of various sizes (41).

The effectiveness of the static guided endodontic surgery has been demonstrated by S. Akermann *et al.* in the study they conducted over teeth from human cadaver. They selected 48 roots which they split into 2 groups of 24 roots each. One group was treated by the guided technique and the other one by the conventional freehand technique. To analyze if the planned path was respected, they superposed preoperative CBCT scans with postoperative CBCT scans. As results, they noted that 100% of the guided treated roots were treated successfully unlike the freehanded treated ones where only 11 out of 24 were treated successfully. Moreover, they noticed that the guided group of roots had an increased accuracy with a mean of 1.473 mm deviation between what was planned and what was performed. The mean deviation for the control group was of 2.638 mm (50).

Although in the available literature, authors have noted major advantages of the guided technique compared to the conventional one, it still has limitations. Among the limitations, authors have found that the space it requires in the mouth of the patient could limit the access for the handpiece. Additionally to this, the potential restoration present on the teeth to treat could produce artefact on the CBCT making it harder to plan the procedure. They have stated as well that the guide could impede optimal irrigation during the surgery.

Surgery using dynamic navigation system

The dynamic navigation system has poorly been investigated in pericapical surgery as it is a very new technique in this field. However, it is still possible to find traces of it in the recent literature. In a study conducted by O. Dianat *et al.* in 2019, they compared endodontic surgery in 2 groups of 20 teeth from cadavers. The surgery was performed by conventional freehand technique in one group and with dynamic system in the other. Subsequently, these two groups were divided each in two other groups, one where the apex of the teeth was at a distance inferior or egal to 5mm from the buccal cortical bone and one group where the apex of the teeth was at a distance superior to 5mm. To compare both techniques, they measured: the linear deviation, the angular deflection and the time required to perform the procedure. The results obtained were greatly in favor of the dynamic guided system. In fact, the mean deviation was largely inferior in the guided system in comparison with the free-hand one. They found lower values for the angular deflection and operating time as well in the dynamic system. An important finding to mention is that there were almost no difference in the subcategories of the dynamic system group whereas there were some in the ones of the free-hand group (50). This study has demonstrated the efficiency of the dynamic guided method regardless of where the apex of the teeth is located from the buccal cortical plate. It is of great interest in complicated case where the root is hard to locate and where possible over preparation of the bone could be done implying risking to damage adjacent structures.

Gianluca Gambarini *et al*. reported in 2019 a case of a 34-year-old patient treated with dynamic system for the periapical surgery. In this case, the treatment was done by a student under the supervision of a tutor to evaluate the importance of the experience when using this technique. He stated that the localization of the apex as was well as the apex resection were done accurately performing a minimally invasive osteotomy preventing iatrogenic damages.

Follow-up controls were done 1-, 3- and 6-months post-operation and great healing of the tissues was noted. Considering the limited discomfort of the patient, they judged the treatment as successful (11).

Dynamic endodontic surgery allows the operator to find the apex easier than in conventional apical surgery where it is one of the major challenges of the procedure (51). Knowing, the relationship between the extension of the osteotomy, the healing process and the post-operative complications, this method has a great potential as it is presented by the authors to be minimally invasive. As for the dynamic system in orthograde root canal treatment, it allows real-time tracking of the bur which impedes the iatrogenic errors and thus further complications. As an advantage over the static system, we find the possibility to modify the plan when performing the procedure to adapt to any unplanned situation. This system enables the less experienced dentists to perform such procedure as it will guide them to the apex conserving as much bone as possible avoiding large bone resection. The operator's experience is not as important as in the free-hand technique. Moreover, the dynamic system presents a shorter surgical instrumentation which permits to use it in area with difficult access such as posterior sector or patient with limited mouth opening.

As for all the guided endodontic procedures, this procedure has an additional cost which could be a limitation. Another drawback of the guided surgery is the need to watch at the device instead of the operation site to check if we are performing the treatment as planned previously.

CONCLUSION

Authors have demonstrated, over the past few years, through case reports and ex vivo studies that guided endodontic techniques appeared as more efficient, more accurate, less time-consuming, less invasive and less operator dependent than free-hand conventional techniques. In none of the articles reviewed, free-hand techniques showed better results than the guided ones.

Regarding guided systems: dynamic one and static one, they both present advantages and disadvantages over the other and this in root canal treatment of PCO or in periapical surgery. The election of which system to use is done according to the case faced and the physical characteristics of the patient. Proper diagnosis is key in selecting the guided system whether static or dynamic.

The principal withdraw of guided endodontics is its additional cost. However, this additional cost can be justified if it allows to maintain the teeth and avoid incorrect treatment leading to iatrogenic errors resulting in bad prognosis in conserving the teeth and thus leading to rehabilitation treatments.

Guided endodontic techniques come from the field of implantology where guided implant systems have largely been investigated. However, even though the authors have demonstrated their efficiency, guided endodontics are still very new techniques. Most of the literature is very recent and mostly rely on case reports or ex vivo studies but it lacks studies conducted over larger time and more standardize methods of assessment are needed to show concrete results that would make this technique a compelling alternative treatment when treating complex cases. High-quality studies are absolutely essential to expose clearly the strengths and limitations of these techniques in order to offer the best outcome as possible to the patient.

Social responsibility

Nowadays, it is greatly assumed that the aim of the modern dentistry is to be as much conservative as possible. Thus, whenever it is possible to “save” a tooth everything should be done in order to conserve it. So even though these new techniques have an additional cost, they can considerably improve the quality of life of the patient as it could “save” teeth that wouldn’t be conserved otherwise.

Moreover, as very new, those techniques open the doors for further bigger investigation, research and development in order to bring out all their potential and why not make them an alternative of choice to save teeth.

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Annexes

Australian Endodontic Journal
The Journal of the Australian Society of Endodontology Inc., the Australian and New Zealand Academy of Endodontists and the Asian Pacific Endodontic Confederation

Aust Endod J 2017; 43: 123–128

ORIGINAL RESEARCH

Comparison of apical centring ability between incisal-shifted access and traditional lingual access for maxillary anterior teeth

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Keywords
3D printing, cone-beam computed tomography, dental pulp cavity, incisor, root canal preparation.

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Abstract

The aim of this study was to compare the apical centring ability of incisal-shifted access (ISA) with that of traditional lingual access (TLA). Fifteen three-dimensional printed resin models were prepared from the computed tomography data for a human maxillary central incisor and divided into ISA ($n = 7$), TLA ($n = 7$) and control ($n = 1$) groups. After access preparation, these models were shaped to the working length using K-files up to #40, followed by step-back procedures. An apical portion of the model was removed at 0.5 mm coronal to the working length. Microscopic images of each cutting surface were taken to measure the preparation area and the distance of transportation. TLA created a larger preparation area than ISA ($P < 0.05$). The distance of transportation (mean $\pm$ standard deviation) was 0.4 ± 0.1 mm for ISA and 0.7 ± 0.1 mm for TLA ($P < 0.05$). Access cavity preparation has a significant effect on apical centring ability. ISA is beneficial to maintaining apical configuration.

Introduction

Appropriate access cavity preparation is essential during root canal treatment. Several authors have suggested that the objectives of access cavity preparation include ensuring straight-line access, removing all debris from the pulp chamber, and securing the seat for the temporary seal (1–3). Smaller access cavity preparation prevents creation of straight-line access in curved root canals, thereby complicating the procedure (4). Access cavity preparation is the first step in root canal treatment and has a significant impact on subsequent procedures.

In the anterior teeth, the outline of access cavity preparation has been traditionally located at the centre of the lingual surface, with a triangular outline form (5,6). In most cases, the direction of traditional lingual access (TLA) cavity preparation is different from the direction of the root canal, especially in its apical third. This is because a discrepancy usually exists between the long axis of the crown and the long axis of the root canal. Laturno and Zillich (7) and Zillich and Jerome (8) have reported that TLA achieved straight-line access in the maxillary central and lateral incisors in only 10% and 0.8% of cases, respectively. In these studies, they also demonstrated that shifting the location of access from the centre of the lingual surface to the incisal edge increases accessibility from the coronal aspect of the root to the apex. Such incisal-shifted access (ISA) allows a greater area of the root canal wall to be accessible to instruments such as Gates Glidden Drills and K-files (9). Therefore, ISA could be an alternative approach to improve straight-line access.

Iatrogenic mishaps such as ledging, zipping, and apical transportation can occur after excessive removal of dentine caused by a number of errors during endodontic procedures (10). Such events may leave sources of infection inside the root canal, leading to a negative prognosis for endodontically treated teeth (11–13). Thus, the ability to maintain the original morphology of the root canal could be directly linked to the clinical success of root canal treatment (10). The improved straight-line access afforded by ISA could maintain the original curvature of

Fracture Strength of Endodontically Treated Teeth with Different Access Cavity Designs

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Abstract

Introduction: The purpose of this study was to compare *in vitro* the fracture strength of root-filled and restored teeth with traditional endodontic cavity (TEC), conservative endodontic cavity (CEC), or ultraconservative "ninja" endodontic cavity (NEC) access. **Methods:** Extracted human intact maxillary and mandibular premolars and molars were selected and assigned to control (intact teeth), TEC, CEC, or NEC groups (n = 10/group/type). Teeth in the TEC group were prepared following the principles of traditional endodontic cavities. Minimal CECs and NECs were plotted on cone-beam computed tomographic images. Then, teeth were endodontically treated and restored. The 160 specimens were then loaded to fracture in a mechanical material testing machine (LR30 K; Lloyd Instruments Ltd, Fareham, UK). The maximum load at fracture and fracture pattern (restorable or unrestorable) were recorded. Fracture loads were compared statistically, and the data were examined with analysis of variance and the Student-Newman-Keuls test for multiple comparisons. **Results:** The mean load at fracture for TEC was significantly lower than the one for the CEC, NEC, and control groups for all types of teeth ($P < .05$), whereas no difference was observed among CEC, NEC, and intact teeth ($P > .05$). Unrestorable fractures were significantly more frequent in the TEC, CEC, and NEC groups than in the control group in each tooth type ($P < .05$). **Conclusions:** Teeth with TEC access showed lower fracture strength than the ones prepared with CEC or NEC. Ultraconservative "ninja" endodontic cavity access did not increase the fracture strength of teeth compared with the ones prepared with CEC. Intact teeth showed more restorable fractures than all the prepared ones. *(J Endod 2017;43:995–1000)*

Key Words

Conservative access cavity, endodontic access cavity, fracture resistance, "ninja" cavity, traditional endodontic cavity

Significance

CEC and NEC access was proposed to reduce fracture risk of endodontically treated teeth. Teeth with CEC and NEC showed similar fracture strength, which was higher than that of teeth with traditional endodontic access.

One of the most important steps for successful endodontic treatment is access cavity preparation. The traditional endodontic cavity (TEC) design for different tooth types has remained unchanged for decades, and only minor modifications have been done (1). However, the removal of tooth structure needed for access cavity preparation may undermine the strength of the tooth to fracture under functional loads (2, 3). Extraction is the most frequent consequence of fracture of endodontically treated teeth (4–6). Extended preparation of endodontic access cavities critically reduces the amount of sound dentin (7–10) and increases the deformability of the tooth (8), compromising the strength to fracture of endodontically treated teeth (7).

Recently, conservative endodontic cavity (CEC) preparation (11, 12) to minimize tooth structure removal and preserve some of the chamber roof and pericervical dentin was reported in the literature. This sound dentin preservation could be achieved with the help of cone-beam computed tomographic (CBCT) imaging to identify all the canals (13, 14). This could improve the fracture strength of endodontically treated teeth (11).

Following this concept, an extreme conservative approach has recently been proposed, which is conventionally known as "ninja." This technique may improve the fracture strength of endodontically treated teeth (15). To date, there are no studies comparing CEC access cavity preparation with ultraconservative "ninja" endodontic cavity (NEC) access. Therefore, the purpose of this study was to investigate the fracture strength of endodontically treated teeth with a TEC, CEC, or NEC access cavity.

Materials and Methods

Specimen Selection and Preparation

After ethics approval, 160 recently extracted intact human maxillary and mandibular molars and premolars from a white population with completely formed apices were used. The exclusion criteria for the tested teeth were the presence of caries, previous restoration, and visible fracture lines or cracks.

After a debridement with hand scaling instruments and cleansing with a rubber cup and pumice, the teeth were stored in individually numbered containers with 0.1% thymol solution at 4°C until used and during all the time between the different phases of the experiment in order to prevent their dehydration.

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Reduction in Tooth Stiffness as a Result of Endodontic and Restorative Procedures

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Endodontically treated teeth are thought to be more susceptible to fracture as a result of the loss of tooth vitality and tooth structure. This study was designed to compare the contributions of endodontic and restorative procedures to the loss of strength by using nondestructive occlusal loading on extracted intact, maxillary, second bicuspids. An encapsulated strain gauge was bonded on enamel just above the cementoenamel junction on both the buccal and lingual surfaces, and the teeth were mounted in nylon rings leaving 2 mm of root surface exposed. Under load control, each tooth was loaded at a rate of 37 N per s for 3 s and unloaded at the same rate in a closed loop servo-hydraulic system to measure stiffness. A stress-strain curve was generated from each gauge prior to alteration of the tooth and after each procedure performed on the tooth. Cuspal stiffness, as a measure of tooth strength, was evaluated on one of two series of sequentially performed procedures: 1. (a) unaltered tooth, (b) access preparation, (c) instrumentation, (d) obturation, and (e) MOD cavity preparation; or 2. (a) unaltered tooth, (b) occlusal cavity preparation, (c) two-surface cavity preparation, (d) MOD cavity preparation, (e) access, (f) instrumentation, and (g) obturation. Results on 42 teeth indicate that endodontic procedures have only a small effect on the tooth, reducing the relative stiffness by 5%. This was less than that of an occlusal cavity preparation (20%). The largest losses in stiffness were related to the loss of marginal ridge integrity. MOD cavity preparation resulted in an average of a 63% loss in relative cuspal stiffness. The results indicate that endodontic procedures do not weaken teeth with intact marginal ridges.

Endodontic treatment is considered to weaken the tooth by increasing the brittleness, leading to a higher susceptibility to fracture. Consequently, the recommended restoration has been cuspal protection with a cast restoration. Clinical studies on large numbers of patients have indicated the need for special restorative considerations for endodontically treated teeth (1–3). One of the largest difficulties with retrospective studies is that only the clinically successful cases are examined (1). The greatest failure rate in endodontically treated teeth was associated with lack of appropriate restoration (2, 3). Teeth are believed to become more brittle as a direct result of endodontic treatment leading to fracture and tooth loss (4). In reality increased brittleness has not been proven. Hardness measurements of endodontically treated teeth that were treated up to 10 yr previously indicated no difference in hardness between endodontically treated and vital teeth (5). Similiarly, punch shear testing on endodontically treated teeth showed only a small (although statistically significant) reduction in strength of 14% (6).

Restorative procedures (not in relation to endodontic treatment) have been examined to determine their contribution to the resistance of the tooth to fracture. Statistical differences were difficult to demonstrate for restorative procedures due to the destructive nature of these tests. To overcome the problem of sample variation, large numbers of samples are needed. It has been shown that the resulting weakening of the tooth due to restorative procedures increases with the reduction of tooth structure (7, 8). According to Larson et al. (8) occlusal cavities significantly weaken the tooth and wider isthmus preparations result in the largest decrease of tooth resistance to fracture. Factors such as the maintenance of marginal ridge integrity and width of the isthmus region also appear to be important in reducing tooth fracture (7, 9). The conclusions that could be drawn from previous work are that the preservation of tooth structure is important in maintaining resistance to fracture, especially by preserving marginal ridges and maintaining narrow isthmus.

According to Hood (10), nondestructive techniques employing linear variable differential transformers, which measure small movements of tooth structure under load, provide one method to examine the effects of sequential treatments. The relative contributions of restorative and endodontic procedures could be more accurately assessed, within physiological limits, using this technique. Hood observed that a small reduction of tooth structure, such as an occlusal cavity preparation, produced a significant decrease in tooth rigidity. Endodontic procedures also significantly decreased tooth rigidity reflecting a decreased stiffness in the tooth (10).

Other sources are in agreement that the removal of hard tissue increased cuspal flexure under occlusal load (11, 12). Morin et al. (13) state that the use of strain gauges also permit the visualization of hysteresis. Hysteresis, which is the state of being behind, in strain gauge measurements would be the

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REVIEW

Clinical applications, accuracy and limitations of guided endodontics: a systematic review

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Abstract

Moreno-Rabié C, Torres A, Lambrechts P, Jacobs R. Clinical applications, accuracy and limitations of guided endodontics: a systematic review. *International Endodontic Journal*, **53**, 214–231, 2020.

Background The novel concept of guided endodontics has been reported as an effective method to obtain safe and reliable results during several endodontic treatments.

Aim To evaluate by means of a systematic review the clinical applications, accuracy and limitations of guided endodontic treatment.

Data sources A search of the literature was performed on PubMed, Embase, Web of Science and Cochrane Library databases, until 25 April 2019. No language or year restrictions were applied.

Study eligibility criteria Articles that answered the research question, including case reports, *in vitro* and *ex vivo* studies were included. Data extraction was performed independently by two reviewers.

Study appraisal Quality assessment was done using STROBE, CARE and Modified CONSORT guidelines for observational, case reports and pre-clinical studies, respectively.

Results A total of 22 articles, including fifteen case reports, six pre-clinical studies (*in vitro* and *ex vivo* studies) and one observational study, were included.

Limitations and Conclusions Even though the level of evidence is low, and the methodology described among studies heterogeneous, all articles describe guided access cavity preparation and guided surgery as being highly accurate and successful techniques when comparing the drilled path to the planned treatment. More studies with a larger number of patients are necessary to obtain significant conclusions.

Keywords: 3D printed template, cone beam computed tomography, guided access, guided endodontics, guided surgery.

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Introduction

Pulp canal obliteration (PCO) is the deposition of hard tissue within the root canal space (McCabe & Dummer 2012). It is commonly associated with teeth having a history of trauma (Holcomb & Gregory 1967, Andreasen *et al.* 1987, Oginni *et al.* 2009, McCabe & Dummer 2012), following orthodontic treatment (Delivanis & Sauer 1982, Andreasen *et al.* 1987), in response to pulpal injuries (Agamy *et al.* 2004), dental caries (Sayegh & Reed 1968), restorative procedures or abfractions (Fleig *et al.* 2017), and in teeth of elderly patients (Sayegh & Reed 1968, Johnstone & Parashos 2015, Kiefner *et al.* 2017).

In such cases, if root canal treatment is indicated, the treatment is more challenging compared to a tooth with a wide and patent canal (Robertson *et al.* 1996). The access cavity will be difficult to align

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CASE REPORT

Microguided Endodontics: a method to achieve minimally invasive access cavity preparation and root canal location in mandibular incisors using a novel computer-guided technique

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Abstract

Connert T, Zehnder MS, Amato M, Weiger R, Kühl S, Krastl G. Microguided Endodontics: a method to achieve minimally invasive access cavity preparation and root canal location in mandibular incisors using a novel computer-guided technique. *International Endodontic Journal*, **51**, 247–255, 2018.

Aim To present a novel miniaturized and minimally invasive treatment approach for root canal localization in mandibular incisors with pulp canal calcification and apical periodontitis.

Summary A 51-year-old male patient presented with pain from his mandibular incisors. The patient had a history of severe dental trauma over 30 years ago. Both mandibular central incisors (teeth 31, 41) were tender to percussion and had a yellowish discoloration. They did not respond to thermal and electrical sensitivity tests. Two periapical radiographs from different projections revealed severe pulp canal calcifications and signs of periapical periodontitis. To facilitate the 'Microguided Endodontics' technique, a CBCT and an intra-oral surface scan were aligned using special software. This allowed the virtual planning of optimal access cavities up to the apical third of the root. In this technique, a 3D-printed template guides a customized drill to the orifice of the root canal. After negotiation of the root canals, conventional root canal treatment was performed. This case report demonstrates that minimally invasive and apically extended access cavities are feasible in mandibular incisors with this technique.

Key learning points

- The 'Microguided Endodontics' technique is a safe and minimally invasive method for root canal location and prevention of technical failures in anterior teeth with pulp canal calcification.

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Guided Endodontics Modified for Treating Molars by Using an Intracoronal Guide Technique

Check for updates

Jorgen Buchgreitz, DDS, Mikkel Buchgreitz, DDS,* and Lars Bjorndal, DDS, PhD, Dr Odont, DDSc*[†]

Abstract

The aim of this case report was to show the concept of guided endodontics in a maxillary first molar with limited interocclusal space. Guided endodontics involves merging cone-beam computed tomographic imaging and a surface scan of the tooth in order to create a guide to perform a drill path into the seemingly obliterated root canal. In the molar region, the interocclusal space is often too small to accommodate the guide, bur, and handpiece at once, and, therefore, a modified approach is presented. A 52-year-old man was referred because the dentist had failed to localize the distobuccal root canal of a maxillary molar (#3) associated with apical pathosis. After reopening and rubber dam placement, a glide path was established for both the palatal first mesiobuccal root canal and the second mesiobuccal using a size 10 hand file and coronal flaring. Further instrumentation to the working length was achieved by reciprocating file size 25. All 3 canals were temporarily filled with calcium hydroxide. For the distobuccal root canal, guided endodontics was chosen in order to avoid further impairment of the tooth because negotiation of the canal failed even with the use of the operating microscope. Following the merged data obtained from the cone-beam computed tomographic and surface scans, a translucent SICAT Optiguide (SICAT, Bonn, Germany) was constructed containing a sleeve representing the proper direction of a drill path in order to reach the distobuccal root canal. The access cavity was temporarily filled with a composite material made for light-curing. Before light curing, the Optiguide was replaced on the teeth, and a steel pin was pressed through the sleeve and the composite whereby the proper drill path direction was transferred into the composite. After polymerization and removal of the Optiguide and pin from the composite base sleeve, the guided drilling could be performed. This case report is the first on guided access preparation in a molar with pulp canal obliteration and limited interocclusal space. The demand for more interocclusal space was solved by transforming the virtual drill path into a composite-based intracoronal guide. The use of digital technology was essential. (*J Endod* 2019;45:818–823)

Key Words

Access cavity, cone-beam computed tomography, endodontics, guided endodontics, pulp canal obliteration

Significance

Molars are the most frequent tooth in need of RCT. In cases of canal obliteration, they can be treated using a guided endodontic concept. If the interocclusal distance is reduced, the concept can be changed by using an intracoronal guide.

Guided endodontics is a new approach to localizing and negotiating seemingly obliterated root canals. By planning the root canal treatment beforehand in 3 dimensions on the volume of a cone-beam computed tomographic (CBCT) scan and merging this with a surface scan, it is possible to manufacture a template to guide the treatment. The construction of guides was recently introduced for scouting obliterated root canals (1, 2). Buchgreitz et al (1) were the first to show that guided access principles, later known as "guided endodontics," were accurate enough to be used *in vivo*. Tertiary dentin formation resulting from caries activity (3) or after restorative procedures (4) as well as during traumatic injuries (5–7) may lead to the narrowing of the pulp chamber. Despite the introduction of an operating microscope, the localization and negotiation of obliterated root canals can be a prolonged and complex procedure (8). It may also lead to operator errors during preparation of the access cavity, including the risk of root perforation as well as separation of files during the shaping of the root canals. This includes obvious medicolegal considerations (9). Based on several case reports, guided endodontics seems to be a safe and predictable method (10–15). Most recently, we have consistently shown, based on 50 cases of referred single-rooted teeth, precision of the guided drill path leading to successful negotiation of partly or seemingly complete pulp canal obliteration (16). These positive results were observed regardless of possible influences from demographic variables including treatment status and extent of actual root canal obliteration (16). Guided endodontics has mostly been applied on incisors and premolars but can be used on molars as well if the interocclusal space is large enough for the guide, bur, and handpiece (17). The aim of this case report was to show a modification of guided endodontics with the purpose of reducing the need for interocclusal space using an intracoronal guide technique whereby it can be applied more often in the posterior region.

Materials and Methods

A 52-year-old white man was referred to the dental office (endodontic referral clinic in Allerød, Denmark) in 2016 for endodontic treatment of the maxillary right first molar (#3). The patient's dental history revealed that treatment had been initiated by the referring dentist but given up and then referred because it was only

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Guided Endodontic Access of Calcified Anterior Teeth

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Abstract

Pulp canal calcification is characterized by the deposition of calcified tissue along the canal walls. As a result, the root canal space can become partially or completely obliterated. Recently, "guided endodontics" has been reported as an alternative solution in cases of partial or completed canal obliteration. Although this technique can enhance minimally invasive access to the calcified canal, it has been shown that the incisal surfaces are often removed during the access of anterior teeth. This report describes 2 cases of guided endodontics using conventional palatal access in calcified anterior teeth and discusses the applicability of this approach in cases of pulp canal calcification with apical periodontitis and acute symptoms. The method demonstrated high reliability and permitted proper root canal disinfection expeditiously, without the unnecessary removal of enamel and dentin in the incisal surface. *(J Endod 2018;44:1195–1199)*

Key Words

Apical periodontitis, dental trauma, guided endodontics, opening access, pulp canal calcification

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Significance

Guided endodontics often causes incisal edge removal in anterior teeth. Guided endodontics programmed with conventional palatal access showed high reliability and permitted root canal disinfection expeditiously.

Pulp canal calcification (PCC), also known as pulp canal obliteration or calcific metamorphosis, is characterized by the deposition of calcified tissue along the canal walls. As a result, the root canal space can become partially or completely obliterated. PCC cases are associated with luxation injuries after dental trauma (1, 2). Other causes of PCC are a pulpal response to injuries such as invasive pulp therapy procedures (3), extended carious lesions (4), abfractions, and restorations (5). The use of orthodontic forces may also induce PCC because of interference in the blood supply (6). Moreover, in elderly patients, the deposition of secondary dentin may also severely reduce the root canal space (7, 8).

An incidence of 4% of partial or total obliteration of the pulp spaces of anterior teeth was reported by Holcomb and Gregory (9) in servicemen. In cases of traumatized permanent teeth, this incidence is increased to 22% (10). Pulp necrosis has been reported in 1%–16.5% of PCC cases (11), and the development of apical periodontitis has been estimated at 7.3%–24% of cases after 4 years of trauma (2). There is a consensus in the literature that the root canal treatment of teeth presenting with PCC is only indicated in the presence of acute symptoms or apical periodontitis (1, 2, 9–15). In these cases, even the most experienced clinicians can encounter difficulties in achieving the goals of endodontic treatment. Root perforation and canal deviations have been reported as common complications after the treatment of PCC cases, which may ultimately result in tooth loss (16, 17).

Recently, "guided endodontics" has been reported as an alternative solution in cases of partial or completed canal obliteration (18, 19). Special software (coDiagnostix; Dental Wings Inc, Montreal, Canada) aligned with cone-beam computed tomographic (CBCT) imaging and a digital impression 3-dimensional (3D) scan allows virtual planning of the canal access cavity. Subsequently, a 3D template can be produced to guide the drill into the calcified root canal (20). Although this technique can enhance minimally invasive access to the calcified canal, it has been shown that the incisal edge is often removed during the access of anterior teeth to allow for straight-line access parallel to the long axis of the tooth for the drill (18–20). To avoid this, a modification in the template was proposed to permit standard access preparation for maxillary anterior teeth, which is located in the exact center of the palatal surface of the crown buccolingually and incisogingivally.

These reports aimed to describe 2 cases of guided endodontics programmed with conventional palatal access in anterior teeth and to discuss the applicability of this approach in cases of PCC with apical periodontitis and acute symptoms.

Case Report 1

A 43-year-old female patient was referred to a private clinic with a history of pain in the maxillary right central incisor. The patient had a history of dental trauma that occurred 25 years earlier. The tooth was discolored and yellow, and it presented

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A decision analysis for periapical surgery: Retrospective Study

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Abstract

Background: Periapical surgery is now a reliable therapeutic procedure for the treatment of teeth with periapical lesions, particularly when orthograde retreatment is problematic. However, little information is available regarding treatment planning of cases referred for periapical surgery. Therefore, this study was conducted to analyze and evaluate the factors that affect the decision-making process for periapical surgery.

Material and Methods: This study retrospectively assessed clinical and radiographic data from patients undergoing periapical surgery. The factors involved in deciding to perform periapical surgery were classified into technical, biological, and combined factors.

Results: Out of 821 patients, 544 (66.3%) underwent endodontic treatment/retreatment, 204 (24.8%) were treated with coronal restorations and 60 (7.3%) were treated with post. Periapical surgery was indicated for biological reasons in 35% of patients and for technical reasons in 17.9%. The common biological factor was persistent clinical symptoms (19.7%). The most common technical cause was failure of previous endodontic treatment (66.3%). Nearly half of all periapical lesions (45%) were >5 mm in size. Periapical surgery was justified in only 434 (52.9%) subjects.

Conclusions: We suggest that it is very important for patients to be informed and encouraged about endodontic retreatment in order to reduce unnecessary surgical procedures.

Key words: *Periapical surgery, case selection, treatment planning.*

Introduction

Persistent apical periodontitis following orthograde root-canal treatment is common among adult populations in various countries, with prevalence rates varying between 27%-70% and increasing with age (1). Conventional root-canal treatment is considered to be the best method of managing periapical disease, with success rates varying between 48%-98% (2). If root canal treatment fails, the reasons for this must be accurately assessed before any further intervention. Whenever possible, nonsurgical retreatment is regarded as the treatment of choice. However, where nonsurgical retreatment is not an option, periapical surgery (endodontic surgery) is considered to be a viable alternative (2). In order to eli-

Computer-aided Design/Computer-aided Manufacturing–guided Endodontic Surgery: Guided Osteotomy and Apex Localization in a Mandibular Molar with a Thick Buccal Bone Plate

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Abstract

A mandibular molar with a thick buccal bone plate is a challenging problem in endodontic surgery despite the increase in the success rate of endodontic surgery nowadays. This report describes the application of a surgical template to guide osteotomy and facilitate apex localization in a mandibular molar with a thick buccal bone plate. A 57-year-old woman visited the authors' clinic for pain in tooth 19 and was diagnosed with symptomatic apical periodontitis in this previously treated tooth. Nonsurgical retreatment was performed; however, 2 years later, the patient reported pain in the same tooth. A periapical lesion was confirmed using cone-beam computed tomographic (CBCT) imaging, and endodontic surgery on the mesial root of tooth 19 was planned. After CBCT imaging and cast scan data were transferred to implant surgical planning software, the data were superimposed. In the superimposed model, an anchor pin was designed to target the mesial root apex of tooth 19. The surgical template was then printed using a 3-dimensional printer. Endodontic microsurgery included application of this printed surgical template. A computer-aided design/computer-aided manufacturing (CAD/CAM)-guided surgical template minimized the extent of osteotomy and enabled precise targeting of the apex in this case. There were no postoperative complications. A CAD/CAM-guided surgical template is useful in endodontic surgery for complicated cases. (*J Endod 2018;44:665–670*)

Key Words

3D printing, apical surgery, computer-aided design/computer-aided manufacturing, endodontic surgery, surgical guide

Significance

Introducing a CAD/CAM-guided surgical template in endodontic surgery would make guided osteotomy and precise targeting of the root apex possible. The surgical template would be especially useful in performing endodontic surgery on teeth with potentially problematic anatomic structures.

Computer-aided design/computer-aided manufacturing (CAD/CAM) and 3-dimensional (3D) printing technology were first developed and applied in the late 1980s and 1990s (1). Currently, CAD/CAM and 3D printing have diverse applications in dentistry including the fabrication of dental models, temporary restorations, surgical guides for orthognathic surgery, and trays for indirect bonding of orthodontic brackets (1). Surgical guide templates using CAD/CAM and 3D printing, in particular, are commonly used in implant surgery (2). These templates have also been recently introduced in endodontic fields. Templates used in orthograde guide access cavity preparation in calcified canals (3) and guided osteotomy in endodontic surgery have been described (4, 5).

Endodontic surgery is 1 of the treatment options to manage persistent apical periodontitis after the failure of nonsurgical treatment (6). The success rate of conventional endodontic surgery is relatively low, between 43.5% and 74% (7). However, by applying contemporary techniques, including high-power magnification and illumination, microsurgical instruments, and modern filling materials (8), success rates of surgery have significantly increased, and, in turn, surgery has become a more effective treatment. Success rates for endodontic microsurgery have been reported to be between 88.9% and 100% (7).

Prognostic factors influencing endodontic surgery outcomes include lesion type, root-end filling material, and coronal restoration, among others (9). Some studies have found that tooth position also has an influence on outcome(s). In particular, the lower molars have been reported to have lower success rates than teeth in other positions. The difficulty in accessibility caused by thick buccal bone and anatomic obstacles, including the mental foramen or inferior alveolar nerve, has been attributed to poorer outcomes (10, 11).

Another factor known to be associated with improved and faster healing is the extent of periapical bony destruction (12). The extent of osteotomy also influences the degree of postoperative complications such as pain and swelling (13). However, the extent of osteotomy tends to be increased in cases with an intact buccal bone plate

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Case Report

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The application of "bone window technique" using piezoelectric saws and a CAD/CAM-guided surgical stent in endodontic microsurgery on a mandibular molar case

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Conflict of Interest
No potential conflict of interest relevant to this article was reported.

ABSTRACT

Apical surgery for a mandibular molar is still challenging for many reasons. This report describes the applications of computer-guided cortical 'bone-window technique' using piezoelectric saws that prevented any nerve damage in performing endodontic microsurgery of a mandibular molar. A 49-year-old woman presented with gumboil on tooth #36 (previously endodontically treated tooth) and was diagnosed with chronic apical abscess. Periapical lesions were confirmed using cone-beam computed tomography (CBCT). Endodontic microsurgery for the mesial and distal roots of tooth #36 was planned. Following the transfer of data of the CBCT images and the scanned cast to an implant surgical planning program, data from both devices were merged. A surgical stent was designed, on the superimposed three-dimensional model, to guide the preparation of a cortical window on the buccal side of tooth #36. Endodontic microsurgery was performed with a printed surgical template. Minimal osteotomy was required and preservation of the buccal cortical plate rendered this endodontic surgery less traumatic. No postoperative complications such as mental nerve damage were reported. Window technique guided by a computer-aided design/computer-aided manufacture based surgical template can be considerably useful in endodontic microsurgery in complicated cases.

Keywords: Endodontic microsurgery; Bone window; Surgical guide; Computer-aided design/Computer-aided manufacturing; Piezoelectric surgery

INTRODUCTION

Endodontic microsurgery is the treatment option frequently opted to manage endodontically failed cases with persistent apical periodontitis, after nonsurgical root canal treatment [1,2]. The success rate of conventional apical surgery is relatively low, ranging between 43.5% and 74% [3]. However, the application of current techniques, including magnification and illumination provided by the microscope, new microsurgical instruments, and new root-end filling materials [4], have improved the success rates of endodontic surgery remarkably, and subsequently, surgical retreatment has become an effective treatment option for cases

CASE REPORT/CLINICAL TECHNIQUES

Endodontic Microsurgery Using Dynamic Navigation System: A Case Report

Gianluca Gambarini, MD, DDS, Massimo Galli, MD, Luigi V. Stefanelli, DDS, Dario Di Nardo, DDS, PhD, Antonio Morese, DDS, Marco Seracchiani, DDS, Francesca De Angelis, DDS, Stefano Di Carlo, DDS, and Luca Testarelli, DDS, PhD

ABSTRACT

Dynamic navigation systems were introduced to facilitate dental implantology by improving the accuracy of dental implant positioning. Dynamic navigation integrates surgical instrumentation and radiologic images by using an optical positioning device controlled by a dedicated computerized interface. These features could help in reducing the risk of unintentional iatrogenic damage to nearby anatomic structures and perform minimally invasive or flapless surgery, leading to reduced patient postoperative discomfort and improved healing. The present case report showed the use of the Navident dynamic navigation system (ClaroNav, Toronto, Ontario, Canada) by an undergraduate student for bone cavity preparation and root-end resection in the surgical endodontic treatment of a lesion in an upper lateral incisor. The system allowed precise localization of the root and precise apicoectomy with a minimal invasive cavity. The dynamic navigation system allowed the student to precisely direct the bur in 3 dimensions. The osteotomy and root-end resection were easily and quickly performed by the undergraduate student with a minimally invasive approach without iatrogenic errors. The navigation system allowed the operator to precisely perform a minimally invasive osteoctomy and root-end resection during endodontic surgery. The development of dedicated surgical navigation systems for endodontic surgery could facilitate the operator's maneuvers and reduce the risk of iatrogenic errors. *(J Endod 2019;45:1397–1402.)*

KEY WORDS

Apicoectomy; dynamic navigation surgery; microsurgery; Navident

SIGNIFICANCE

The dynamic navigation system allowed a nonexperienced operator to precisely perform a minimally invasive osteoctomy and root-end resection during endodontic surgery. Dynamic navigation is a promising technology aiming at facilitating the surgical procedures and reducing the risk of iatrogenic errors.

Dynamic navigation systems were introduced to facilitate dental implantology by improving the accuracy of dental implant positioning[1,2]. Dynamic navigation integrates surgical instrumentation and radiologic images using an optical positioning device controlled by a dedicated computerized interface. A clinical real-time interface displays and guides users to drill into the targeted position through the prefixed trace according to the output of the preoperative planning software[3].

Navident (ClaroNav, Toronto, Ontario, Canada) is an easy-to-use, accurate, portable system that offers dental surgeons an affordable way to plan implant placement on a virtual patient and then insert the fixture with greater accuracy and real-time 3-dimensional control provided by a computer-assisted procedure (Supplemental Figs. S1–S6). These features could help in reducing the risk of unintentional iatrogenic damage to nearby anatomic structures and perform minimally invasive or flapless surgery, leading to reduced patient postoperative discomfort and improved healing[4,5]. An *in vitro* study showed that the Navident dynamic navigation system allowed more accurate implant placement in comparison with the conventional freehand method, regardless of the surgeon's experience. However, the system seemed to offer more advantages to novice professionals because it allows them to reduce their deviations significantly and achieve results similar to those of experienced clinicians[6].

Even if the studies published to date were related to implant placement, with the exception of 1 *in vitro* study concerning locating canals in extracted teeth, the dynamic navigation system could also be used for endodontic procedures[7] regarding locating calcified canals, minimally invasive access cavity in orthograde endodontics, and surgical endodontics. To date, planned and guided endodontic procedures have been proposed only with static systems using 3-dimensional printed templates but only for nonsurgical procedures[8–10].

One of the main problems in surgical endodontics is preparing a minimally invasive bone cavity to allow enough space to perform a correct apicoectomy, retrograde filling, and mechanical elimination of the lesion. Surgical endodontics is a complex retreatment option that requires skill and experience[11].

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A clinical and roentgenological study of 55 cases of root perforation

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Summary. The treatment outcome of 55 root perforations in man were related to pretreatment conditions and various treatment procedures used, with a mean recall period of 3 years 5 months. In this study maxillary teeth were perforated three times more often (74.5 per cent) than mandibular teeth (25.5 per cent); 47 per cent of the perforations were due to endodontic and 53 per cent due to prosthodontic treatment. The buccal and mesial root surfaces as well as the midroot areas were most often perforated. In 25 per cent, radiographic changes were directly related to the perforated areas.

Twenty-eight perforations were repaired by orthograde fillings with gutta-percha and Kloroperca N-Ø; eight received a combined orthograde and surgical repair, and in only three cases a surgical approach was used. Four cases received no treatment but were recalled, and twelve perforations showed a size and location hopeless for repair; the teeth were therefore extracted. Five failures of the primary orthograde treatment group later underwent surgical treatment and were followed up for 3 years 3 months.

The overall success rate in the primary treatment group of teeth was 56 per cent while 36 per cent became failures. Five failures were retreated, and four of these became successful. A combined orthograde and surgical repair of the perforations provided the most favourable outcome with 92 per cent successful.

The study stresses the importance of preventing this type of treatment complication.

Introduction

Root perforations may occur as a complication during endodontic treatment or dowel (post) preparation. Frequencies of such complications have been reported to occur in up to 3 per cent (Bergenholtz *et al.* 1979, Kerekes & Tronstad 1979).

A number of papers dealing with root perforations have been published, and different treatment procedures have been recommended on the basis of observations from animal experiments (Lantz & Persson 1965, 1967, Seltzer *et al.* 1970, Petersson *et al.* 1985), or on short-term clinical follow-up studies (Nicholls 1962, ElDeeb *et al.* 1982). A few studies have dealt with long-term results (Strömberg *et al.* 1972, Harris 1976). Since there is little consistency concerning the treatment procedures and the criteria used for evaluation of the treatment results, it is difficult to compare the outcome of different studies. However, several investigators have reported favourable results after repairing root perforations.

It is the purpose of this paper to present the aetiology and location of 55 root perforations in from a dental school clinic, and to relate their outcome to the pretreatment conditions and various procedures used to treat the perforations.

Material and Methods

Over a period of 11 years, 55 root perforations were recorded at the Department of Cariology and Endodontics, School of Dentistry, Bergen, Norway. Forty-four of these perforations were diagnosed during endodontic or prosthodontic treatment, seven during routine endodontic recall and four prior to endodontic retreatment.

Pretreatment evaluation and treatment selection

For perforations diagnosed during treatment procedures, radiographs taken from different horizontal angles were used to determine the accessibility and location of the perforations.

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Failures and healing in endodontically treated non-vital anterior teeth with posttraumatically reduced pulpal lumen

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Cvek, M., Granath, L. & Lundberg, M. Failures and healing in endodontically treated non-vital anterior teeth with post-traumatically reduced pulpal lumen. *Acta Odontol. Scand.* 1982, 40, 223–228

The aim of the present investigation was to assess the frequency of technical failures as well as the 4-year results of endodontic treatment in non-vital incisors with post-traumatically reduced pulpal lumen. In 54 teeth the smallest width of the root canal was measured and classified as 0, ≤ 0.1, > 0.1 – ≤ 0.2 or > 0.2 mm. The total frequency of failures was 20%. In upper incisors it was 15–17% in the classes up to a root canal width of 0.2 mm. In lower incisors with no or only partially visible root canal it was 71% and in the class up to 0.1 mm 10%, the difference being significant at the 5% level. The total frequency of healing after 4 years was 80%, while in teeth with a technical failure at the time of treatment the frequency was 50%. The difference between the group without and that with technical failures was statistically significant at the 5% level.

Key-words: Endodontics; traumatology; pedodontics

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Endodontic treatment in accidentally injured teeth has been recommended to be instituted as soon as a progressive hard-tissue formation, diminishing the pulpal lumen, is observed radiographically (4, 8). In a previous study, however, it was demonstrated that the tissue changes of the pulps in such teeth subjected to preventive treatment were not indicative for endodontic intervention (7). Therefore, evaluation of endodontic treatment in teeth with post-traumatically reduced pulpal lumen should be restricted to teeth that have become non-vital in the late stage of obliteration. It has been said that pulp canals of such teeth may be surprisingly negotiable (10), but in general, the treatment is looked on as impossible or extremely difficult to perform. No investigation on the frequency or nature of failures is, however, on record.

In a clinical situation, the accessibility for treatment is judged from the radiographic image of the root canal. Therefore, it appears justified to study the frequency of technical failures in relation to the extent of which the root canal is visible in the radiograph obtained before treatment.

The aim of the present paper was to assess the frequency of technical failures as well as the 4-year results of endodontic treatment in non-vital teeth with post-traumatically reduced pulpal lumen of varying degrees.

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CLINICAL ARTICLE

WILEY

Endodontic treatment of dens evaginatus by performing a splint guided access cavity

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Abstract

Aim: Dens evaginatus (DE) is described as an unusual dental malformation. Tooth structure variations attached to this anatomical disturbance complicates the performance of a conservative access cavity for a conventional root canal treatment. Author's purpose is to describe the treatment of a type V DE by using splits as guides to perform access cavity.

Clinical considerations: This clinical case shows a root canal treatment of a type V DE diagnosed by using a cone beam computed tomography (CBCT). Access cavity was planned through an osseointegrated implant planning software and guided by a stereolithographied split. After endodontic treatment, tooth was sculpted for placing a veneer, processed by a chair-side system in a single session.

Conclusions: CBCT is an effective method for obtaining internal anatomical information of teeth with anatomical malformations. The osseointegrated implant planning software is an effective method for planning root canal treatment and designing stereolithograped splits (for performing minimally invasive access cavities).

CLINICAL SIGNIFICANCE

Stereolithographed splints allow performing a guided and conservative access cavity of teeth affected by dental malformations whereas digital technology allows us to esthetically reconstruct a tooth in a single session.

KEYWORDS
dens evaginatus, guided endodontics, chairside system

1 | INTRODUCTION

Dens evaginatus (DE), which includes malformations such as interstitial cusp, tuberculated premolar, odontoma of the axial core type, evaginated odontoma, occlusal enamel pearl, occlusal anomalous tubercle, supernumerary cusp, and Leong's premolar, is defined as an unusual dental malformation arising during the odontogenesis process.[1]

Dens evaginatus is thought to originate from an abnormal proliferation and folding of the inner portion of the enamel epithelium and subjacent ectomesenchymal cells of dental papilla into the stellate reticulum of the enamel organ during the bell stage of tooth formation. The resulting formation is defined as a tubercle, or supplemental solid elevation on some portion of the crown surface.[2,3]

In the literature, dens evaginatus is defined as an uncommon developmental aberration of a tooth, that results in the formation of a supernumerary tubercle extending from the occlusal aspect of an otherwise normal tooth.[4]

This unusual tooth surface anomaly contains a prolongation of pulpal tissue covered by a thin layer of enamel and dentin. The presence of pulp inside the tubercle has major clinical importance and helps us to distinguish from supplementary cuspids, such as Carabelli's cuspid,

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Guided Endodontics: a novel treatment approach for teeth with pulp canal calcification and apical pathology

CASE REPORT

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Key words: Dental trauma; pulp canal calcification; root canal treatment; guided endodontics; template; apical periodontitis

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Abstract – *Aim:* To present a new treatment approach for teeth with pulp canal calcification (PCC) which require root canal treatment. *Case:* A 15-year-old male patient presented with pain of his upper right central incisor. The tooth showed signs of apical periodontitis. Due to PCC, location of the root canal was judged to be difficult and associated with a high risk of perforation. A cone beam computed tomography (CBCT) and an intra-oral surface scan were performed and matched using software for virtual implant planning. After planning the position of the drill for root canal location, a virtual template was designed, and the data were exported as an STL file and sent to a 3D printer for template fabrication. The template was positioned on the anterior maxillary teeth. A specific drill was used to penetrate through the obliterated part of the root canal and obtain minimally invasive access to the apical part. The root canal was accessible at 9 mm distance from the apex. Further root canal preparation was carried out using an endodontic rotary instrumentation system. After an interappointment dressing for 4 weeks, the root canal was filled with vertically condensed gutta-percha using an epoxy sealer. The access cavity was restored with a composite material. After 15 months, the patient was clinically asymptomatic with no pain on percussion. The radiograph showed no apical pathology. *Conclusions:* The presented guided endodontic approach seems to be a safe, clinically feasible method to locate root canals and prevent root perforation in teeth with PCC.

It is well documented that luxation injuries affect both the periodontium and the pulp (1). The fate of the pulp tissue varies according to the intensity of the injury and the stage of root development (2). Extensive physical trauma may result in either partial or total rupture or stretching of the neurovascular supply to the pulp at the apical foramen. Thus, pulp necrosis is a frequent event, especially in teeth with completed root formation (3).

In immature teeth, however, revascularization and reinnervation of the pulp may occur in the absence of infection, if the size of the apical foramen is sufficiently great to allow vascular ingrowth.

If the revascularization process is successful or in cases of milder injuries with pulp survival after the trauma, regressive pulp changes can occur and may result in accelerated apposition of new hard tissue in the root canal (4).

This process usually starts in the coronal portion of the root canal and is followed by gradual narrowing of the pulp space (5).

The greatest frequency of PCC in immature teeth is encountered among lateral luxations (71%) followed by extrusions (61%). In intrusion cases, pulp necrosis is the predominant healing complication (4). PCC is considered as a sign of pulpal healing and does not require any endodontic intervention – regardless of the result of the pulp sensitivity test (6, 7).

From an aesthetical point of view, yellow crown discoloration, which is frequently associated with PCC, can be successfully treated with external bleaching or placement of a veneer (8).

In the initial phase of PCC, particularly during the first 3 years, apical pathology is very unlikely. However, the development of pulp necrosis and periapical changes may occur as a late complication after several uneventful years (9). Secondary pulp necrosis after PCC indicated by periapical bone lesions was reported in 7–27% of the cases and seems to increase with longer observation periods (4, 7, 10, 11).

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Guided access cavity preparation using cone-beam computed tomography and optical surface scans – an *ex vivo* study

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Abstract

Buchgreitz J, Buchgreitz M, Mortensen D, Bjørndal L. Guided access cavity preparation using cone-beam computed tomography and optical surface scans – an ex vivo study. *International Endodontic Journal*, **49**, 790–795, 2016.

Aim To evaluate *ex vivo*, the accuracy of a preparation procedure planned for teeth with pulp canal obliteration (PCO) using a guide rail concept based on a cone-beam computed tomography (CBCT) scan merged with an optical surface scan.

Methodology A total of 48 teeth were mounted in acrylic blocks. An apical canal preparation was created to simulate remnants of an apical root canal that acted as the target for a drill path. The test blocks were surface scanned, and merged with a CBCT scan, and a guide rail was made. A pathway for the bur was created through a metal sleeve within the guide rail into dentine. The distance was measured between the centres of the performed drill path and the apical target by two examiners. A maximum distance of 0.7 mm was defined based on the radius of the bur (0.6 mm) and the radius of a root canal just visible on a radiograph (0.1 mm). The t-test was used for evaluation, and intra- and inter-examiner reproducibility was expressed by intraclass correlation coefficients.

Results The mean distance between the drill path and the target was significantly lower than 0.7 mm, and null hypothesis H_0: $\mu = 0.7$ was rejected (CI 95%: 0.31;0.49, $P < 0.001$). Intra- and inter-examiner agreements reached excellent levels.

Conclusions The combined use of CBCT and optical scans for the precise construction of a guide rail led to a drill path with a precision below a risk threshold. The present technique may be a valuable tool for the negotiation of partial or complete pulp canal obliteration.

Keywords: access cavity, CBCT, endodontics, pulp canal obliteration, trauma.

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Introduction

The canal system may partly or completely obliterate as a consequence of physiological ageing and/or external injuries, such as attrition, caries, previous operative procedures, as well as trauma (Andreasen & Kahler 2015, Qassem *et al.* 2015). Root canal treatment is only advocated when apical periodontitis develops (Robertson *et al.* 1996) or with signs such as tenderness to percussion, PAI scores ≥3 and a negative response to sensibility testing (Oginni *et al.* 2009). Traumatized incisors with radiographic signs of pulp canal obliteration (PCO) most often represent clinically complete PCO and may pose particular diagnostic and treatment challenges (McCabe & Dummer 2012). The American Association of Endodontists Case Assessment criteria place these cases into the high difficulty category (American Association of Endodontists 2010).

During cavity preparation, the location of the original (but obliterated) pulp canal may be detected as a

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CASE REPORT

Microguided Endodontics: a method to achieve minimally invasive access cavity preparation and root canal location in mandibular incisors using a novel computer-guided technique

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Abstract

Connert T, Zehnder MS, Amato M, Weiger R, Kühl S, Krastl G. Microguided Endodontics: a method to achieve minimally invasive access cavity preparation and root canal location in mandibular incisors using a novel computer-guided technique. *International Endodontic Journal*, **51**, 247–255, 2018.

Aim To present a novel miniaturized and minimally invasive treatment approach for root canal localization in mandibular incisors with pulp canal calcification and apical periodontitis.

Summary A 51-year-old male patient presented with pain from his mandibular incisors. The patient had a history of severe dental trauma over 30 years ago. Both mandibular central incisors (teeth 31, 41) were tender to percussion and had a yellowish discoloration. They did not respond to thermal and electrical sensitivity tests. Two periapical radiographs from different projections revealed severe pulp canal calcifications and signs of periapical periodontitis. To facilitate the 'Microguided Endodontics' technique, a CBCT and an intra-oral surface scan were aligned using special software. This allowed the virtual planning of optimal access cavities up to the apical third of the root. In this technique, a 3D-printed template guides a customized drill to the orifice of the root canal. After negotiation of the root canals, conventional root canal treatment was performed. This case report demonstrates that minimally invasive and apically extended access cavities are feasible in mandibular incisors with this technique.

Key learning points

- The 'Microguided Endodontics' technique is a safe and minimally invasive method for root canal location and prevention of technical failures in anterior teeth with pulp canal calcification.

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A systematic review on the accuracy and the clinical outcome of computer-guided template-based implant dentistry

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Conflicts of interest:
The authors declare no conflicts of interest.

Key words: computer-guided implant dentistry, dental implants, image-guided surgery

Abstract

Introduction: The aim of this systematic review was to analyze the dental literature regarding accuracy and clinical application in computer-guided template-based implant dentistry.

Materials and methods: An electronic literature search complemented by manual searching was performed to gather data on accuracy and surgical, biological and prosthetic complications in connection with computer-guided implant treatment. For the assessment of accuracy meta-regression analysis was performed. Complication rates are descriptively summarized.

Results: From 3120 titles after the literature search, eight articles met the inclusion criteria regarding accuracy and 10 regarding the clinical performance. Meta-regression analysis revealed a mean deviation at the entry point of 1.07 mm (95% CI: 0.76–1.22 mm) and at the apex of 1.63 mm (95% CI: 1.26–2 mm). No significant differences between the studies were found regarding method of template production or template support and stabilization. Early surgical complications occurred in 9.1%, early prosthetic complications in 18.8% and late prosthetic complications in 12% of the cases. Implant survival rates of 91–100% after an observation time of 12–60 months are reported in six clinical studies with 537 implants mainly restored immediately after flapless implantation procedures.

Conclusion: Computer-guided template-based implant placement showed high implant survival rates ranging from 91% to 100%. However, a considerable number of technique-related perioperative complications were observed. Preclinical and clinical studies indicated a reasonable mean accuracy with relatively high maximum deviations. Future research should be directed to increase the number of clinical studies with longer observation periods and to improve the systems in terms of perioperative handling, accuracy and prosthetic complications.

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Prosthetic rehabilitation with implant-supported prostheses is considered to be a routine procedure with high success rates (Hammerle et al. 2002; Pjetursson et al. 2007; Jung et al. 2008). Before implant placement the preoperative diagnostics usually include an analysis of conventional two-dimensional radiographs regarding the availability of bone and identification of relevant anatomic structures. Radiographic templates representing the prosthetic set-up are often applied in terms of planning the optimal implant position on radiographs. The same templates can be used as a prosthetic reference during implant surgery. However, with this kind of preoperative planning the third dimension of the patient's anatomy is missing. Although in medicine, computer tomography has been providing three-dimensional

Computer Technology Applications in Surgical Implant Dentistry: A Systematic Review

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Purpose: *To assess the literature on the accuracy and clinical performance of static computer-assisted implant surgery in implant dentistry.* **Materials and Methods:** *Electronic and manual literature searches were applied to collect information about (1) the accuracy and (2) clinical performance of static computer-assisted implant systems. Meta-regression analysis was performed to summarize the accuracy studies. Failure/complication rates were investigated using a generalized linear mixed model for binary outcomes and a logit link to model implant failure rate.* **Results:** *From 2,359 articles, 14 survival and 24 accuracy studies were included in this systematic review. Nine different static image guidance systems were involved. The meta-analysis of the accuracy (24 clinical and preclinical studies) revealed a total mean error of 1.12 mm (maximum of 4.5 mm) at the entry point measured in 1,530 implants and 1.39 mm at the apex (maximum of 7.1 mm) measured in 1,465 implants. For the 14 included survival studies (total of 1,941 implants) using static computer-assisted implant dentistry, the mean failure rate was 2.7% (0% to 10%) after an observation period of at least 12 months. In 36.4% of the treated cases, intraoperative or prosthetic complications were reported, which included: template fractures during the surgery, change of plan because of factors such as limited primary implant stability, need for additional grafting procedures, prosthetic screw loosening, prosthetic misfit, and prosthesis fracture.* **Conclusion:** *Different levels of quantity and quality of evidence were available for static computer-assisted implant placement, with tight-fitting high implant survival rates after only 12 months of observation in different indications achieving a variable level of accuracy. Future long-term clinical data are necessary to identify clinical indications; detect accuracy; assess risk; and justify additional radiation doses, effort, and costs associated with computer-assisted implant surgery.*
Int J Oral Maxillofac Implants 2014;29 (suppl):25–42. doi: 10.11607/jomi.2014suppl.g1.2

Key words: *guided surgery, dental implants, computer planning*

Prosthetically driven implant surgery in reference to surrounding anatomical structures has been a subject of interest to dental clinicians for a number of years. Correct implant positioning has a number of advantages such as a favorable esthetic and prosthetic outcome and the potential to ensure optimal occlusion and implant loading. Moreover, the consideration of correct implant positioning may enable design optimization of the final prostheses, allowing for adequate dental hygiene. Consequently, all of these factors may contribute to the long-term success of dental implants.

The introduction of cone-beam computed tomography (CBCT) scanning to implant dentistry as a three-dimensional (3D) imaging tool has led to a breakthrough in this field, particularly because these scanning devices result in lower radiation dosages than conventional computed tomography (CT) scanners.[1–3] In combination with implant planning software, the use of CBCT images has made it possible to virtually plan the optimal implant position regarding surrounding vital anatomical structures and future prosthetic needs. The resulting planning information is then used to fabricate so-called drill guides, and this process ultimately results in the transfer of the planned implant position from the computer to the patient, with the

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Guided Endodontics versus Conventional Access Cavity Preparation: A Comparative Study on Substance Loss Using 3-dimensional–printed Teeth

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Abstract

Introduction: The aim of this *in vitro* study was to compare endodontic access cavities in teeth with calcified root canals prepared with the conventional technique and a guided endodontics approach regarding the detection of root canals, substance loss, and treatment duration. **Methods:** Six identical sets of upper and lower jaw models were produced with 3-dimensional–printed incisors that had simulated calcified root canals. Splints for guided access preparations were fabricated based on 3-dimensional surface scans and cone-beam computed tomographic data sets. Under simulated clinical conditions, 3 operators with different levels of experience prepared access cavities on each front tooth with the conventional technique and guided endodontics (8 teeth per technique and operator). Access cavities were volumetrically assessed on postoperative cone-beam computed tomographic scans. Statistical significance was tested by examining the overlap of 95% confidence intervals (CIs). **Results:** Canal location was successful in 10 of 24 cases (41.7%) using the conventional technique and 22 of 24 cases (91.7%) with the guided approach. The mean substance loss of the conventional access and the guided access was 49.9 mm^3 (95% CI, 42.2–57.6 mm^3) and 9.8 mm^3 (95% CI, 6.8–12.9 mm^3), respectively. The treatment lasted 21.8 minutes (95% CI, 15.9–27.7 minutes) for the conventional technique and 11.3 minutes (95% CI, 6.7–15.9 minutes) for guided endodontics. The success of the guided approach was not influenced by the experience of the operator. **Conclusions:** Guided endodontics allows a more predictable and expeditious location and negotiation of calcified root canals with significantly less substance loss. *(J Endod 2019;45:327–331)*

Key Words

3-dimensional–printed teeth, guided endodontics, printed templates, pulp canal calcification, root canal treatment, substance loss

Endodontic access to calcified root canals is a challenging task. It is prone to technical failures including alterations of the root canal geometry and substantial loss of dental hard tissue, which may weaken a tooth considerably or result in root perforation (1).

Significance

Endodontic treatment of teeth with pulp canal calcifications is challenging and may be associated with a high loss of dental hard tissue. "Guided endodontics" provides a highly accurate technique for the preparation of minimally invasive access cavities.

"Guided endodontics," a novel guided approach for the preparation of apically extended access cavities, was introduced to overcome such complications (2–5).Miniaturization of conventional instruments has made this technique implementable even for teeth with narrow roots such as mandibular incisors (6, 7). This technique proved to be accurate, expeditious, and operator independent in *in vitro* settings (2, 6). Although clinical treatment trials are missing, recent clinical case reports show the successful application of this technique in endodontic practice (3, 7, 8).

However, there is a paucity of comparative evidence regarding root canal location in calcified teeth through conventional and guided approaches. The aim of the present *in vitro* study was to compare the conventional technique with the guided approach for root canal location in 3-dimensional (3D)-printed teeth with simulated calcified root canals regarding:

1. the detection and negotiation of root canals,
2. the amount of substance loss, and
3. treatment duration. Second, the influence of the operator's experience was assessed for both techniques.

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0099-2399/$ - see front matter

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Guided Endodontic Access in Maxillary Molars Using Cone-beam Computed Tomography and Computer-aided Design/Computer-aided Manufacturing System: A Case Report

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Abstract

The aim of this study was to describe a guided endodontic technique that facilitates access to root canals of molars presenting with pulp calcifications. A 61-year-old woman presented to our service with pain in the upper left molar region. The second and third left molars showed signs of apical periodontitis confirmed by the cone-beam computed tomographic (CBCT) scans brought to us by the patient at the initial appointment. Conventional endodontic treatment was discontinued given the difficulty in locating the root canals. Intraoral scanning and the CBCT scans were used to plan the access to the calcified canals by means of implant planning software. Guides were fabricated through rapid prototyping and allowed for the correct orientation of a cylindrical drill used to provide access through the calcifications. Second to that, the root canals were prepared with reciprocating endodontic instruments and rested for 2 weeks with intracanal medication. Subsequently, canals were packed with gutta-percha cones using the hydraulic compression technique. Permanent restorations of the access cavities were performed. By comparing the tomographic images, the authors observed a drastic reduction of the periapical lesions as well as the absence of pain symptoms after 3 months. This condition was maintained at the 1-year follow-up. The guided endodontic technique in maxillary molars was shown to be a fast, safe, and predictable therapy and can be regarded as an excellent option for the location of calcified root canals, avoiding failures in complex cases. *(J Endod 2018;44:875–879)*

Key Words

Calcification, cone-beam computed tomography, endodontic access, intraoral scanning, prototyped guides

Significance

The guided endodontic technique in maxillary molars was shown to be fast, safe, and predictable and an excellent option for the localization of calcified root canals, avoiding failures in complex cases.

The root canal system may be partially or completely obliterated as a result of physiological aging or external aggressions, such as friction, caries, previous restorative procedures, and trauma (1, 2). Endodontic treatment is recommended when there are signs and symptoms of the presence of apical periodontitis (3).

The American Association of Endodontists has regarded the endodontic therapy of calcified root canals as having a high level of difficulty (4). Long-neck drills and ultrasonic inserts are strategies routinely used in this type of procedure. However, they still generate a high risk of failure, even when associated with visual magnification with the use of an operating microscope (5–8). Apicoectomy is another alternative for the treatment of calcified canals. Nevertheless, the location of the obliterated canal and adequate cleaning of the contaminated region after root resection are challenging, which explain why this surgical treatment is not the first choice (8).

Three-dimensional (3D) imaging may be an extremely useful tool for safer interventions, and it has become very important in all areas of dentistry, including endodontics (9, 10). In 2015, members of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology gathered to define 12 clinical situations in which cone-beam computed tomographic (CBCT) imaging would be indicated (11). In this context, CBCT imaging has been recently recommended in endodontics as a diagnostic aid in the planning and execution of root canal treatments because of its enhanced capacity to reveal the detailed morphology of the roots (12, 13) and to locate calcified root canals.

The virtual planning and guided access procedure for calcified root canals may help to preserve the tooth structure and avoid accidents such as deviations and perfo-

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CASE REPORT

Access to original canal trajectory after deviation and perforation with guided endodontic assistance

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Keywords
calcification, cone beam computed tomography, endodontic, periapical periodontitis, scanning.

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Abstract

Procedural accidents are eventualities that may occur during endodontic treatment because of lack of attention to detail or even unforeseeable situations. Knowledge of the root canal anatomy and its variations is a prerequisite for successful endodontic treatment. This case report describes an endodontic treatment where there was an intercurrence, generating deviation and perforation, which was solved with the aid of guided endodontics. A 37 years old, ASA1, was referred to the clinic for localisation and treatment of a calcified canal of the second right upper premolar. The tomographic images revealed the presence of only one canal and deviation with apical perforation. With the help of CBCT and CAD/CAM, it was possible to perform the guided access technique even after deviation and root perforation. Once again, this technique proved to be safe and predictable, allowing for a favourable prognosis in the long term.

Introduction

Procedural accidents are eventualities that may occur during endodontic treatment because of lack of attention to detail or even unforeseeable situations (1,2). Knowledge of the root canal anatomy and its variations is a prerequisite for successful endodontic treatment (3). The presence of additional canals or deviations should be avoided, because incomplete instrumentation and maintenance of bacteria and debris that may result in apical periodontitis (3).

One common complication during root canal negotiation and shaping is deviation from the original path (2,4), making it difficult or even impossible to reach the working length (5). Thus, with inadequate instrumentation and obturation, failure of endodontic treatment may occur (5). Inadequate preparation of the access cavity, false estimation of the direction of the root canal and attempts to access calcified canals favour the formation of deviations (1,5).

Endodontic treatment in cases of severely calcified canals is a challenge and is associated with an increased rate of technical failure and a reduced prognosis (6,7). In cases of failures that result in perforations, 75% occur at the time of localisation and negotiation in calcified canals (8).

When the root canal is severely calcified, as identified by radiographic examination, and associated with apical periodontitis and symptomatology, endodontic treatment is indicated, and the access and location of the remaining canal with the aid of guided endodontics have been shown to be safe and predictable (9–12). The combined use of cone beam computed tomography (CBCT) and intraoral optical scanning of the region of interest may potentiate the accuracy of guided drilling for the production of access guides (13,14). Guided access may be a useful tool for the treatment of these complex cases, even without the use of operative microscopy (9,10,15–20).

The use of guided endodontics was recently used and reported by some authors (10,15–20). This method is

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Factors associated with root canal ledging during instrumentation

Kapalas A, Lambrianidis T. Factors associated with root canal ledging during instrumentation. Endod Dent Traumatol 2000; 16: 229–231. © Munksgaard, 2000.

Abstract – The purpose of this study was to identify the presence of a ledge in 141 cases treated in an undergraduate clinic and in 103 cases treated by endodontists, and to identify the clinical factors associated with ledging. A total of 626 root canals were examined and the factors analyzed were canal location, tooth number and canal curvature. The results indicated that 51.5% of the canals treated by students had been ledged, whereas the percentage was 33.2% for intact pulp cavities treated by endodontists and 40.6% in cases of endodontic retreatment. Canal location was found to have an effect on the incidence of ledging as the mesiobuccal, mesiolingual and distal buccal root canals exhibited a significantly higher ledge incidence rate than the distal and palatal root canals. Canal curvature was the most significant variable affecting the incidence of ledging.

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Key words: canal preparation; ledging
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Among the complications most commonly observed during root canal instrumentation is the deviation from the original canal curvature resulting in the formation of a "ledge". Ledging may exclude the possibility of achieving a round preparation reaching the working length, resulting in incomplete instrumentation and obturation of the root canal. Consequently, there may be a causal relationship between ledging and treatment failure (1). The main iatrogenic errors associated with ledging are:

1. Inadequate access cavity preparations
2. False estimation of the root canal direction
3. Erroneous length determination of the root canal
4. Use of straight steel instruments in severely curved root canals
5. Failure to use the instruments in sequential order
6. Attempt to retrieve broken instruments or filling material during endodontic retreatment
7. Attempt to prepare calcified root canals (2).

Only few data are available regarding the frequency of ledge formation and the clinical factors associated with its occurrence. Greene & Krell (3) have examined radiographically cases treated by third-year dental students in an attempt to associate ledging with clinical factors such as tooth number, canal location, working length, the master apical file (MAF) size and root canal curvature. They found that 46% of the canals had been ledged and this percentage increased significantly in teeth where the root canal curvature exceeded 20°. Canal curvature, tooth number and canal location were also found to be main variables associated with ledge formation (3). Stadler et al. (4) have compared the results of two instrumentation techniques in a study comprising 520 roots and recorded a total of 52 incidents of lateral deviation. The incidence of ledging and instrument breakage was more frequent when the reaming technique was used, whereas root perforation and overfilling occurred more often with the filing technique.

In a study of endodontic retreatment, Bergenholtz et al. (5) have examined 660 teeth that were to be retreated for either technical reasons or the presence of periapical radiolucencies. They found that 25% of the root canals retreated for technical reasons and 11% retreated because of the presence of periapical pathosis were obstructed at the level of the previous root filling. Ledging may possibly have had a significant correlation with these cases.

Most available studies fail to provide sufficient evidence to sustain any suggestions about possible factors

Comparison of Endodontic Diagnosis and Treatment Planning Decisions Using Cone-beam Volumetric Tomography Versus Periapical Radiography

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Abstract

Introduction: Accurate and confident treatment planning is an essential part of endodontic practice. Periapical radiographs have been used to aid in the diagnosis of pathology and to help establish an appropriate treatment strategy. Recently, a new imaging modality, cone-beam volumetric tomographic (CBVT) imaging, has been shown to be a useful tool in a number of endodontic applications. The aim of this study was to compare the relative value of preoperative periapical radiographs and CBVT scanning in the decision-making process in endodontic treatment planning. **Methods:** Thirty endodontic cases completed in a private endodontic practice were randomly selected to be included in this study. Each case was required to have a preoperative digital periapical radiograph and a CBVT scan. Three board-certified endodontists reviewed the 30 preoperative periapical radiographs. Two weeks later, the CBVT volumes were reviewed in random order by the same evaluators. The evaluators were asked to select a preliminary diagnosis and treatment plan based solely on their interpretation of the periapical and CBVT images. Diagnosis and treatment planning choices were then compared to determine if there was a change from the periapical radiograph to the CBVT scan. **Results:** A difference in treatment plan between the 2 imaging modalities was recorded in 19 of 30 cases (63.3%, $P = .001$), 17 of 30 cases (56.6%, $P = .012$), and 20 of 30 cases (66.7%, $P = .008$) for examiners 1, 2, and 3, respectively. **Conclusions:** Under the conditions of this study, preoperative CBVT imaging provides additional information when compared with preoperative periapical radiographs, which may lead to treatment plan modifications in approximately 62% of the cases. *(J Endod 2014;40:910–916)*

Key Words

Clinical decision making, cone-beam computed tomography, cone-beam volumetric tomography

In endodontics, clinical examination and diagnostic imaging are both essential components of the preoperative diagnosis (1). Accurate diagnostic imaging supports the clinical diagnosis and allows the clinician to better visualize the area in question. Conventional 2-dimensional (2D) radiographs provide a cost-effective, high-resolution image, which continues to be the most popular method of imaging today. However, the diagnostic potential of periapical radiographs is limited. Information may be difficult to interpret, especially when the anatomy and background pattern are complex (2).

Cone-beam volumetric tomographic (CBVT) imaging is a diagnostic imaging modality that provides a 3-dimensional (3D) image of the maxillofacial region. The term *CBVT*, as used in this study, is synonymous with cone-beam computed tomographic imaging. CBVT scanning is capable of providing images at a low radiation dose and with sufficient spatial resolution for applications in endodontic diagnosis and treatment planning. Furthermore, CBVT imaging overcomes many limitations with conventional radiography such as early detection of invasive cervical resorption lesions, vertical root fractures, and 3D evaluation of the root canal space and surrounding anatomy (3–10). Diagnostic information directly influences treatment planning and clinical decisions. Accurate data lead to better treatment decisions and potentially more predictable outcomes (11).

Although conventional periapical radiography has been used for many years as a diagnostic aid in endodontics, some studies now show the inferiority of periapical radiographs in detecting pathology when compared with CBVT imaging (12–16). CBVT scanning has been successfully used in endodontics, and several recent studies have shown the advantages of CBVT imaging over periapical radiographs (17–21). However, research to support the position that information obtained from a CBVT scan has an actual impact on treatment planning is currently unavailable.

There has been considerable debate regarding whether or not CBVT imaging should be used as a standard preoperative imaging modality in endodontics. The primary argument against routine preoperative CBVT imaging before endodontic therapy relates to the additional ionizing radiation. The effective radiation dose to patients when using CBVT imaging is higher than conventional 2D radiography, and, therefore, the benefit to the patient must outweigh any potential risks of the additional radiation exposure. Radiation dose should be kept as low as reasonably achievable (22, 23). The value of CBVT imaging for endodontic diagnosis and treatment planning should be determined on an individual basis to ensure that the risk/benefit assessment supports its use. CBVT imaging should not be used to simply verify what is already known to be present but rather to help visualize unknown

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Other journals in brief

A selection of abstracts of clinically relevant papers from other journals.

The abstracts on this page have been chosen and edited by John R. Radford.

ABSTRACTS

SHAPE MEMORY ALLOYS

Nickel–titanium (NiTi) arch wires: the clinical significance of super elasticity

Pandis N, Bourauel CP. *Semin Orthod* 2010; **16:** 249–257

Is the new superior to the old?

Pseudoelasticity (superelasticity) is the 'response to an applied stress, caused by a phase transformation between the austenitic and martensitic phases of a crystal'. This narrative review focuses on the use of such shape memory alloys in orthodontics. Archwires formed from pseudoelastic alloys are marketed as offering longer intervals between visits, yet at the same time generating ideal forces for tooth movement. However, when compared with the properties of conventional alloys, they are more expensive, difficult to shape, cannot be soldered or welded and corrode. In addition, clinical studies have not been able to demonstrate any 'significant differences (between tooth movement) among superelastic, nonsuperelastic NiTi wires, and multistranded stainless-steel wires.' For a robust examination of the literature, access *Cochrane Database of Systematic Reviews* 2010, Issue 4. Art. No.: CD007859.

DOI: 10.1038/sj.bdj.2011.644

ORTHODONTIC NEED

Comparison of orthodontic treatment need by professionals and parents with different socio-demographic characteristics

Do an AA, Sari E *et al. Eur J Orthod* 2010; **32:** 672–676

Intriguingly, there is a perception that girls and those children from affluent backgrounds would not to the same degree as others, benefit from orthodontic treatment.

In this cross-sectional study, the orthodontic need of 208 Turkish children was assessed by their parents and one orthodontist only. This abstract will describe only results for the aesthetic component (AC) of the IOTN. Parents of girls, compared with boys '...tended to rate their children's dentition towards the more attractive end of the AC scale'. If fathers had received continuing/higher education, parents perceived the dental appearance of their children more favourably. Likewise, the orthodontist scored this component higher if the child was from a more affluent background. The orthodontist also considered when compared with parents, a higher proportion (51.4% v 33.6%) of the children had a need for treatment in order to improve their dental aesthetic.

DOI: 10.1038/sj.bdj.2011.645

CONE-BEAM COMPUTED TOMOGRAPHY

Editorial: "All that glitters is not gold": standards for cone-beam computerized tomographic imaging

Scarfe WC. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2011;
DOI: 10.1016/j.tripleo.2011.01.006

Nonmaleficence, entrepreneurialism and beneficence.

The author explores tensions in the use of cone-beam comput(eris)ed tomography (CBCT), from the perspective of different 'stakeholders'. For a child who is particularly susceptible to radiation, a front-page article in *The New York Times* highlighted concerns with the use of CBCT in orthodontics. Conflict of interests between the manufacturer and dentist were also identified. For example, the 'dental trades' provide 'sponsored' continuing dental education. Then there are strains between those 'touting the use of CBCT imaging as a method of increasing practice revenues' and those whose role is fiscal control. Many of the legal issues rehearsed in this editorial pertain to American State Law. Nevertheless, there would appear to be a universal requirement that the entire image volume should be interpreted.

DOI: 10.1038/sj.bdj.2011.646

MIXED MESSAGES

Use of cone-beam-computed tomography in endodontics. Joint Position Statement...

Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011; **111:** 234–7, *J Endod* 2011; **37:** 274–277 and www.aae.org/guidelines

Inconsistencies in this Joint Position Statement as to the uses of cone-beam-computed tomography (CBCT) in endodontics.

In contrast to conventional planar radiography, CBCT allows visualisation of teeth and surrounding structures in three dimensions and, in addition, it overcomes some of the issues associated with 'complex anatomy and surrounding structures'. This Guideline and Position Statement 1) reports the results of a web-based survey of members of the American Association of Endodontists, and then 2) makes recommendations as to the uses of CBCT. Despite over one third of respondents stating that they used CBCT, it is recommended that 'CBCT must not be used routinely for endodontic diagnosis or for screening purposes...' and used only as '...an adjunct to two-dimensional imaging in dentistry.' Yet this has to be balanced with 'informed refusal'. When informed refusal is made, it is suggested that the practitioner must state in the clinical notes why the patient has declined CBCT.

DOI: 10.1038/sj.bdj.2011.647

Microguided Endodontics: Accuracy of a Miniaturized Technique for Apically Extended Access Cavity Preparation in Anterior Teeth

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Abstract

Introduction: The aim of this study was to assess the accuracy of guided endodontics in mandibular anterior teeth by using miniaturized instruments. This technique is designed to treat teeth with pulp canal calcifications and narrow roots by using a printed template that guides a bur to the calcified root canal. **Methods:** Sixty sound mandibular anterior teeth were used in 10 mandibular models. Preoperative surface and cone-beam computed tomography scans were matched by using the coDiagnostix software. Virtual planning was performed for the access cavities, and templates were used for guidance. The templates were produced by a three-dimensional printer. Two operators performed the access cavities. A postoperative cone-beam computed tomography scan was superimposed on the virtual plan, and the deviation was measured in 3 dimensions and angles. Descriptive statistical analyses were performed, and 95% confidence intervals were calculated for both operators and each measured aspect. **Results:** The deviations between the planned- and prepared-access cavities were low, with means ranging from 0.12 to 0.13 mm for different aspects at the base of the bur and 0.12 to 0.34 mm at the tip of the bur. The mean of angle deviation was 1.59°. A considerable overlap of the 95% confidence intervals indicated no significant difference between the operators. The mean treatment time, including planning and preparation, was approximately 10 minutes per tooth. **Conclusions:** Microguided endodontics provides an accurate, fast, and operator-independent technique for the preparation of apically extended access cavities in teeth with narrow roots such as mandibular incisors. *(J Endod 2017;43:787–790)*

Key Words

Accuracy, guided endodontics, printed templates, pulp canal calcification, root canal treatment

Significance

Endodontic treatment of teeth with pulp canal calcifications is very challenging and associated with a high technical failure rate. Microguided endodontics provides an accurate technique for the preparation of access cavities and is therefore of high clinical relevance.

Pulp canal calcification (PCC) is a common sequela of dental trauma and may occur in 15%–40% of patients after luxation injuries (1, 2). In elderly patients, PCC may develop because of a lifelong apposition of the secondary and tertiary dentin (3). Furthermore, orthodontic treatment may initiate the accelerated deposition of secondary dentin (4, 5).

PCC is considered a sign of pulp vitality, and unless there is clinical and radiographic evidence of pulp necrosis, root canal treatment is not indicated (6).

However, up to one third of teeth with PCC may develop apical pathology in the long term (7). Root canal treatment is very challenging in these cases and is associated with a high failure rate, especially in mandibular incisors (8). Therefore, the American Association of Endodontists rated the treatment of teeth with PCC as having a high difficulty level (9).

Even with the use of a dental microscope, the preparation of an adequate access cavity may lead to excessive substance loss that impairs stability and thereby reduces the long-term prognosis of the tooth (10).

Recently, a new treatment approach for teeth with PCC by using a printed template with incorporated sleeves that guide the bur to the calcified root canal has been developed (11, 12). This technique provides an accurate access cavity and has already been used in the clinic (13–15).

In these studies, mainly maxillary teeth had been treated. The sizes of the burs used (diameter, 1.2–2.4 mm) are not suitable for the treatment of teeth with PCC and narrow roots such as mandibular incisors.

Therefore, the aim of this study was to assess the accuracy of guided endodontics in mandibular anterior teeth by using miniaturized instruments.

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The Prognosis for Endodontic Treatment of Obliterated Root Canals

Anna Åkerblom, DDS, and Gunnar Hasselgren, DDS, PhD

Teeth with obliterated root canals were treated endodontically without any surgical procedure. Clinical and radiographic follow-up examinations were performed for 2 to 12 yr. The overall success rate was found to be 89%. When the preoperative periapical status was taken into consideration, the success rate for roots with an intact periapical contour was 97.9%. In teeth with preoperative periapical radiolucencies, a success rate of 62.5% was noted.

In the ideal endodontic case, the root canal is patent from the orifice to the apical foramen. However, this is not always the case. Canals may be obliterated by denticles or secondary dentin formation, or the anatomy of the root may prevent proper instrumentation. There are various opinions in the literature regarding the prognosis for endodontic treatment of such canals. According to Strindberg (1) the prognosis is good even in teeth with nonvital pulps. However, according to others, e.g. Nicholls (2), Luks (3), Weine (4), Grossman (5), Bence (6) and Barnes (7), the prognosis must be considered unfavorable if the pulp is necrotic and surgical treatment is therefore recommended. Because of the different opinions about the outcome of endodontic treatment of obliterated root canals, the aim of this investigation was to evaluate the prognosis for such cases.

MATERIALS AND METHODS

All adult patients (2,742) treated during a 10-yr period at the intramural endodontic clinic at the School of Dentistry, University of Lund, Sweden, were followed up for 2 to 12 yr. From these patients all teeth with obliterated roots were selected. The criteria for obliteration were: (a) The root canal was not patent for more than one-third of the root length. (b) No root canal lumen was visible on the radiographs apical to the instrumented portion.

The number of patients with obliterated root canals was 70. Nineteen of those patients failed their recall appointments for different reasons (Table 1). The remaining 51 patients had 64 obliterated roots treated. Periapical radiolucencies were found in 16 roots and 48 roots had an intact periapical contour. The distribution of the treated roots is shown in Table 2. The size of the radiolucencies was measured on the radiographs as the distance from the radiographic apex to the borderline of the radiolucent area. It varied from 1 to 4 mm, with an average size of 2.1 mm.

The teeth were treated under aseptic conditions. Dakin's solution (a 0.5% sodium hypochlorite solution at pH 9) was used for irrigation and calcium hydroxide mixed with sterile water served as dressing between appointments. The instrumented parts of the obliterated roots were filled with gutta-percha (Sybron/Kerr, Romulus, MI) using either colophonium-chloroform (Apoteksbolaget, Göteborg, Sweden) or kloropercha N-O (Tanrac, Gävle Sweden) as sealant.

During the follow-up period (2 to 12 yr), the treated roots were examined radiographically and clinically. Intraoral radiographs were made according to a standardized paralleling technique using a filmholder (Eggen A/S, Lillehammer, Norway) (8), a focus-film distance of about 20 cm and Kodak ultra-speed film (Kodak). A fixed exposure film schedule was used and the radiographs were obtained at 60 kV. The films were developed under standardized conditions.

The preoperative, operative, and follow-up radiographs from the same tooth were all available at the time of evaluation. All radiographs were simultaneously evaluated by two examiners by means of a viewing box with a fixed light intensity and a magnifying viewer (9).

During the clinical examination, the following symptoms were noted: pain, tenderness to percussion or palpation, tooth mobility, and presence of a sinus tract.

The following criteria were used for evaluation of the results: *success*, no clinical symptoms. Normal radiographic width of the periodontal contour; *uncertain*, no clinical symptoms. Radiographically a diffuse or slightly widened periodontal contour; *failure*, clinical symptoms or radiographic evidence of periapical bone destruction.

RESULTS

The treated roots were found to be clinically and radiographically successful in 57 (89%) of the 64 roots (Table 3).

TABLE 1. Reasons for failure of follow-up appointment

	No. of Patients
Change of address	5
Refused follow-up	12
Tooth extracted (reason unknown)	2
	Total 19

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Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location

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Abstract

Zehnder MS, Connert T, Weiger R, Krastl G, Kühl S. Guided endodontics: accuracy of a novel method for guided access cavity preparation and root canal location. *International Endodontic Journal*, **49**, 966–972, 2016.

Aim To present a novel method utilizing 3D printed templates to gain guided access to root canals and to evaluate its accuracy *in vitro*.

Methodology Sixty extracted human teeth were placed into six maxillary jaw models. Preoperative CBCT scans were matched with intra-oral scans using the coDiagnostix™ software. Access cavities, sleeves and templates for guidance were virtually planned. Templates were produced by a 3D printer. After access cavity preparation by two operators, a postoperative CBCT scan was superimposed on the virtual planning. Accuracy was measured by calculating the deviation of planned and prepared cavities in three dimensions and angle. Ninety-five per cent confidence intervals were calculated for both operators.

Results All root canals were accessible after cavity preparation with 'Guided Endodontics'. Deviations of planned and prepared access cavities were low with means ranging from 0.16 to 0.21 mm for different aspects at the base of the bur and 0.17–0.47 mm at the tip of the bur. Mean of angle deviation was 1.81°. Overlapping 95% confidence intervals revealed no significant difference between operators.

Conclusion 'Guided Endodontics' allowed an accurate access cavity preparation up to the apical third of the root utilizing printed templates for guidance. All root canals were accessible after preparation.

Keywords: accuracy, CBCT, guided technique, obliteration, printed templates, root canal treatment.

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Introduction

Treatment and prevention of apical periodontitis is still the major goal of root canal treatment (European Society of Endodontology 2006) and can be achieved by thorough cleaning and shaping of the root canal to eliminate microorganisms (Byström *et al.* 1987). Beforehand, a cavity has to be prepared to gain access to the root canals. This is the first invasive step of every root canal treatment and is thus crucial for the outcome, stability and longevity of the tooth (Trabert *et al.* 1978, Clark & Khademi 2010). To facilitate disinfection and complete debridement, straight line access to the orifices of the root canals is recommended (Mannan *et al.* 2001, Patel & Rhodes 2007, Johnson 2009), but there are also minimal invasive concepts to decrease fracture risk of root filled teeth (Krishan *et al.* 2014).

The number of elderly patients and their need for root canal treatment is increasing (Allen &

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Impacts of Conservative Endodontic Cavity on Root Canal Instrumentation Efficacy and Resistance to Fracture Assessed in Incisors, Premolars, and Molars

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Abstract

Introduction: Conservative endodontic cavity (CEC) may improve fracture resistance of teeth but compromise the instrumentation of canals. This study assessed the impacts of CEC on both variables in 3 tooth types. **Methods:** Extracted human intact maxillary incisors, mandibular premolars, and molars (n = 20/type) were imaged with micro–computed tomographic imaging (20-μm resolution) and assigned to CEC or traditional endodontic cavity (TEC) groups (n = 10/group/type). Minimal CECs were plotted on scanned images. Canals were prepared with WaveOne instruments (Dentsply Maillefer, Ballaigues, Switzerland) using 1.25% sodium hypochlorite and post-treatment micro–computed tomographic images obtained. The proportion of the untouched canal wall (UCW) and the dentin volume removed (DVR) for each tooth type was analyzed with the independent-samples t test. The 60 instrumented and 30 intact teeth (negative control, n = 10/type) were loaded to fracture in the Instron Universal Testing machine (Instron, Canton, MA) (1 mm/min), and the data were analyzed with 1-way analysis of variance and the Tukey test. **Results:** The mean proportion of UCW was significantly higher ($P < .04$) only in the distal canals of molars with CEC (57.2% ± 21.7%) compared with TEC (36.7% ± 17.2%). The mean DVR was significantly smaller ($P < .003$) for CEC than for TEC in incisors (16.09 ± 4.66 vs 23.24 ± 3.38 mm^3), premolars (8.24 ± 1.64 vs 14.59 ± 4.85 mm^3), and molars (33.37 ± 67.71 mm^3). The mean load at fracture for CEC was significantly higher ($P < .05$) than for TEC in premolars (586.8 ± 116.9 vs 328.4 ± 56.7 N) and molars (1586.9 ± 196.8 vs 641.7 ± 62.0 N). In both tooth types, CEC did not differ significantly from the negative controls. **Conclusions:** Although CEC was associated with the risk of compromised canal instrumentation only in the molar distal canals, it conserved coronal dentin in the 3 tooth types and conveyed a benefit of increased fracture resistance in mandibular molars and premolars. *(J Endod 2014;40:1160–1166)*

Key Words

Dentin volume removed, endodontic cavity, fracture resistance, instrumentation efficacy

Traditional endodontic cavity (TEC) designs for different tooth types have remained unchanged for decades with only minor modifications. Highlighting "convenience form" and "extension for prevention" (1), TEC promotes the controlled removal of tooth structure beyond gaining access to canal orifices to facilitate cleaning, shaping, and filling of root canals and to prevent procedural complications (1, 2). Consequent removal of tooth structure, coronal to the pulp chamber, along the chamber walls, and around canal orifices, may undermine the resistance of the tooth to fracture under functional loads (3–5). Indeed, fractures and possible subsequent extraction of root-filled teeth (6–9) have undermined the confidence of dentists and patients in the long-term benefits of endodontic treatment (5, 10).

Recently, Clark and Khademi (10, 11) modified the endodontic cavity design to minimize tooth structure removal. In departure from the completely unroofed, coronally divergent, straight-line access to canal curvatures, the conservative endodontic cavity (CEC) preserves some of the chamber roof and pericervical dentin (10). Clinically, the smallest CEC possible for each tooth can be outlined on cone-beam computed tomographic (CBCT) images (12) by plotting the trajectory toward each canal. Although the preserved tooth structure may offer a benefit of improved fracture resistance under functional loads (5), the confined CEC outline restricts cleaning, shaping, and filling of the root canals (10, 11), increasing the risks of inefficient canal instrumentation and the occurrence of procedural errors (2). Specific investigation into CEC is warranted to assess the associated risks and benefits for different tooth types.

Mechanical efficacy of canal instrumentation is routinely assessed with nondestructive micro–computed tomographic (micro-CT) imaging (13–18). Analysis of pre- and postoperative micro-CT images enables measurements of changes in root canal morphology, including volume of the dentin removed and canal wall surface areas untouched by instruments (13–18). Fracture resistance of teeth is routinely assessed by simulated functional loading in the Instron Universal Testing machine (Instron, Canton, MA) until fracture occurs (19, 20). Loading point, force, and direction can be controlled and the load at fracture recorded (19, 20).

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Impacts of Contracted Endodontic Cavities on Instrumentation Efficacy and Biomechanical Responses in Maxillary Molars

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Abstract

Introduction: Recently, we reported that in mandibular molars contracted endodontic cavities (CECs) improved fracture strength compared with traditional endodontic cavities (TECs) but compromised instrumentation efficacy in distal canals. This study assessed the impacts of CECs on instrumentation efficacy and axial strain responses in maxillary molars. **Methods:** Eighteen extracted intact maxillary molars were imaged with micro–computed tomographic imaging (12-μm voxel), assigned to CEC or TEC groups (n = 9/group), and accessed accordingly. Canals were instrumented (V-Taper2H; SSWhite Dental, Lakewood, NJ) with 2.5% sodium hypochlorite irrigation, reimaged, and the proportion of the modified canal wall determined. Cavities were restored with bonded composite resin (TPH-Spectra-LV; Dentsply International, York, PA). Another 28 similar molars (n = 14/group) with linear strain gauges (Showa Measuring Instruments, Tokyo, Japan) attached to mesiobuccal and palatal roots were subjected to load cycles (50–150 N) in the Instron Universal Testing machine (Instron, Canton, MA), and the axial microstrain was recorded before access and after restoration. These 28 molars and additional 11 intact molars (control) were cyclically fatigued (1 million cycles, 5–50 N, 15 Hz) and subsequently loaded to failure. Data were analyzed by the Wilcoxon rank sum and Kruskal-Wallis tests (α = 0.05). **Results:** The overall mean proportion of the modified canal wall did not differ significantly between CECs (49.7% ± 12.0%) and TECs (44.7% ± 9.0%). Relative changes in axial microstrain responses to load varied in both groups. The mean load at failure for CECs (1703 ± 558 N) did not differ significantly from TECs (1384 ± 377 N) and was significantly lower (P < .005) for both groups compared with intact molars (2457 ± 941 N). **Conclusions:** In maxillary molars tested *in vitro*, CECs did not impact instrumentation efficacy and biomechanical responses compared with TECs. (*J Endod 2016;42:1779–1783*)

Key Words

Endodontic cavity, fracture strength, instrumentation efficacy, minimally invasive, root strain

Significance

Fracture after endodontic treatment is an ongoing concern. Modern dentistry has seen a trend towards minimally invasive treatments. In endodontics, removal of tooth structure increases the susceptibility of teeth to fracture that gave rise to the concept of contracted cavities.

Endodontic treatment aims to retain teeth in health and function for the long-term (1), but teeth may fracture, necessitating extraction (2–4). A fracture risk factor is loss of dentin, including that associated with drilling of endodontic cavities (4). Traditional endodontic cavities (TECs) emphasize straight-line pathways into canals to enhance instrumentation efficacy and prevent procedural errors (5, 6). The associated removal of pericervical dentin (7, 8) can impact biomechanical responses of teeth (9–14). Increased cuspal flexure associated with TECs (9,12–14) may lead to increased strain at the crown and root surfaces (11–13), which, in turn, may increase the susceptibility of treated teeth to fracture under functional loads (4, 9). These biomechanical effects are undesirable, but they may be moderated in the short-term by restoration of endodontic cavities with bonded composite resin (12,15–18).

Contracted endodontic cavities (CECs), inspired by concepts of minimally invasive dentistry (19), emphasize tooth structure preservation including pericervical dentin (7, 8). We previously reported (20) that CECs, compared with TECs, improved fracture strength under a continuous load in unrestored mandibular premolars and molars but not in maxillary incisors, and compromised instrumentation efficacy in distal canals of mandibular molars but not in premolars and incisors. These results, suggesting that the impact of CECs varied in different tooth types when unrestored, might not be extrapolated to restored maxillary molars in which the morphology is distinctly different. Also, unlike available data on fracture strength of intact mandibular molars (21), respective data on maxillary molars are lacking. Therefore, this study assessed the impacts of CECs on canal instrumentation efficacy and biomechanical responses in maxillary molars

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Evaluation of a Simplified Fiber Post Removal System

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Abstract

Introduction: This study investigated the influence of clinical experience in relation to the efficacy and effectiveness of removal of 2 different fiber posts. **Methods:** In total, 48 intact single-rooted teeth were treated endodontically and obturated. Then, 10-mm post spaces were prepared, and fiber posts were luted. Twenty-four #1 D.T. Light-Posts were used in group 1, and 24 #2 Hi-Rem Prosthetic Posts were used in group 2. A pullout test (n = 8 per group) was performed by using a universal testing machine to compare bond strength. Then, fiber post removal efficacy and efficiency were tested. Each group was divided into 2 subgroups (n = 8) according to operator experience. In group 1, fiber posts were removed with an ultrasonic handpiece by using a #3 Start-X tip. In group 2, a size 25/0.04 ProFile was used to remove the central soft polymer macrofiber, and a #2 Largo drill was used to remove the fiber post and luting cement remnants. Post removal times were recorded to evaluate efficacy. Weight change was determined, and post space walls were analyzed microscopically to evaluate effectiveness. **Results:** Bond strength did not differ significantly ($P = .7569$) between post systems. Post hoc Tukey tests indicated that removal time was affected significantly by operator experience in group 1 ($P < .001$) but not in group 2. Weight change was affected significantly by experience level in both groups. No difference in post space wall characteristics was observed between subgroups. **Conclusions:** The Hi-Rem post was easier to remove than the D.T Light-Post. (*J Endod 2013;39:1431–1434*)

Key Words

fiber post, operator experience, post removal, pull-out, weight change

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The restoration of endodontically treated teeth can be complex because of extensive loss of dental structure (1, 2). Intraradicular posts are commonly used to gain additional retention and adequate support when the remaining coronal tissue can no longer provide it (3). Metal-free fiber posts are now considered to be advantageous for improving the performance of restorations (4–7) because their physical properties are similar to those of dentin, and they have improved esthetic properties (8). Several dentin bonding techniques have also been developed to ensure maximal adhesion of post systems (9). Some studies have examined the *in vivo* clinical efficacy of postendodontic restorations supported by fiber posts (10, 11).

Occasionally, a post must be removed to allow nonsurgical endodontic retreatment because of the development or reappearance of periapical pathology (12, 13). In such endodontic retreatment, a fiber post–supported restoration may influence the difficulty of reaching the root canal system and apex. Moreover, the improved bonding of the fiber post to the root canal space may cause additional problems for removal. To facilitate post removal with minimal loss of tooth structure and root damage, many authors have advocated the application of ultrasonic vibration to the post (14–16). However, one potential shortcoming of such ultrasonic treatment is the production of heat. A previous study (17) showed that the application of vibration energy for more than 15 seconds generated a large temperature increase at the root surface; even when higher temperatures are recorded at the post surface than at the root surface, this temperature increase could be dangerous to periodontal ligaments and alveolar bone.

To facilitate fiber post removal, a glass-fiber post with a soft blue polymer macrofiber along its longitudinal axis was recently introduced (Hi-Rem Post; Overfibers, Ferrara, Italy). The manufacturer claims that this fiber post can be removed readily and noninvasively, but no published study has evaluated this claim.

Thus, the purpose of this *in vitro* study was to evaluate the influence of clinical experience in relation to removal time and effectiveness by using 2 different fiber posts. The null hypothesis was that clinical experience would not significantly influence fiber post removal.

Materials and Methods

Specimen Preparation

In total, 48 extracted, intact, human single-rooted teeth with similar root lengths were selected for this study. After root surface debriding, the specimens were stored in 0.5% chloramine. Each tooth was sectioned at the cementoenamel junction, perpendicular to the long axis of the tooth, by using a cylindrical diamond rotary cutting instrument (Intensiv 314, Ø ISO 014, 8.0-mm length; Intensiv, Grancia, Switzerland). Specimens were instrumented endodontically by using #1, #2, and #3 PathFiles (Dentsply Maillefer, Ballaigues, Switzerland) and an S1-S2-F1-F2-F3 ProTaper file sequence (Dentsply Maillefer) to the working length to enlarge the apex to size 30 with a 0.09 taper. The working length was established under ×10 magnification (Pro Magis; Carl Zeiss, Oberkochen, Germany) when the tip of the file became visible at the apical foramen. Irrigation was performed with 5% NaOCl (Niclor 5; Ogna, Muggiò, Italy) alternated with 10% EDTA (Tubuliclean; Ogna) by using a 2-mL syringe and 25-gauge needle. Specimens were obturated with gutta-percha by using a DownPak heat source (Hu-Friedy, Chicago, IL) and endodontic sealer (Pulp Canal Sealer EWT; Kerr, Orange, CA). Backfilling was performed with Obtura III (Analytic Technologies, Redmond, WA). After 24 hours, a post space was prepared in each specimen to a depth of 10 mm from the sectioned surface by using dedicated drills according to the manufacturer's

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The heat generated on the external root surface during post space preparation

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Summary. The heat generated on the external root surface of human premolar teeth during post space preparation was measured *in vitro*. The rise in temperature was recorded at a point 6 mm from the apex of the tooth using a thermocouple attached to a chart recorder. The temperature rise was greatest when the removal of gutta-percha was combined with post channel preparation. Temperature rises of up to 31°C were recorded. Instruments that only removed gutta-percha did not generate the same amount of heat.

The results from this study suggest that the use of engine-driven drills to prepare post channels in teeth may generate temperature rises that may cause periradicular tissue damage, and caution should be exercised during their use.

Introduction

One of the most common methods of restoring root-filled teeth is by means of a post and core. The post is cemented within the prepared root canal, a core is built around and over the post, and a coronal restoration is placed over the core. The length of the post may vary, but the apical 4–5 mm of root filling should not be disturbed to avoid subsequent leakage and failure of the endodontic therapy (Neagley 1969, Zmener 1980).

A number of methods have been advocated for the removal of the coronal part of a gutta-percha root filling prior to post crown preparation (Mattison *et al.* 1982, Madison & Zakariasen 1984). The gutta-percha can be softened using a hot instrument, or by chemical means with chloroform or eucalyptus oil, and then removed mechanically. Removal can also be achieved by mechanical means only, using a Gates Glidden bur, Peeso reamer or the more recently introduced GPX[1] reamer. With all these instruments, no attempt was made to prepare the post channel. Studies have shown that the method by which the root filling is removed prior to preparation of the post channel does not affect the quality of the apical seal (Camp & Todd 1983, Madison & Zakariasen 1984, Suchina & Ludington 1985).

Proprietary engine-driven reamers are available that not only remove the root filling but also prepare the walls of the root canal. These reamers are matched to a particular post configuration which may have tapered or parallel sides. The preparation of the root canal to accept a post involves cutting the dentinal walls precisely so that a matched post may be fitted. Although it is not always necessary to have contact between the post and the root canal along its whole length, a close fit should be achieved apically and coronally (Harty & Leggett 1972). In some cases, this may lead to the removal of considerable amounts of dentine.

Rotating instruments placed within the root canal during the thermomechanical compaction of gutta-percha have been shown to cause a temperature rise on the external surface of the root (Hardie 1986). This can lead to histological changes taking place within the periodontium (Saunders 1988). The generation of heat during this obturation technique is, in part, due to the frictional binding of the rotating instrument against the walls of the root canal. The frictional heat plasticizes the gutta-percha within the canal. Mechanical preparation for a post will also cause frictional binding of the instrument to the canal walls as dentine is cut. Many of the instruments provided for post channel preparation are used

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Implant Placement Is More Accurate Using Dynamic Navigation

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Purpose: The purpose of this prospective study was to measure and compare the accuracy and precision of dynamic navigation with freehand (FH) implant fixture placement. The authors hypothesized that the evaluated dynamic navigation system would have high accuracy and precision and would be superior to FH methods.

Materials and Methods: The authors designed and implemented a prospective cohort study and enrolled patients who had implants placed from December 2014 through December 2016. The predictor variable was implant placement technique comparing fully guided (FG) and partially guided (PG) dynamic navigation with FH placement. The outcome variables were accuracy measured as deviation from the virtual plan, and precision was represented as the standard deviation of the measurements. Analysis of variance (ANOVA) was used to compare measurements. Virtual implant placement was compared with postimplant placement using mesh analysis. Deviations from the virtual plan were recorded for each implant for each surgeon. FH implant placement was evaluated by comparing a virtual plan with postoperative scans for patients who did not have the navigation system used for their implant placement. One-way ANOVA was performed to determine within-group and between-groups differences to determine whether there were meaningful differences among surgeons and methods (FG, PG, and FH) of placement.

Results: Prospective data from 478 patients involving 714 implants were evaluated. There were no demographic differences among surgeons. The sample size differed by the number of implants placed by each surgeon. Within each method group, the only difference among surgeons was angular deviation. All surgeons' data were combined. For FG navigation, the mean angular deviation was $2.97 \pm 2.09°$, the mean global platform position deviation was 1.16 ± 0.59 mm, and the mean global apical position deviation was 1.29 ± 0.65 mm. For PG navigation, the mean angular deviation was $3.43 \pm 2.33°$, the mean global platform position deviation was 1.31 ± 0.68 mm, and the mean global apical position deviation was 1.52 ± 0.78 mm. For FH placement, the mean angular deviation was $6.50 \pm 4.21°$, the mean global platform position deviation was 1.78 ± 0.77 mm, and the mean global apical position deviation was 2.27 ± 1.02 mm. Differences in measurements comparing FG and PG navigation with FH indicated significantly less deviation from the virtual plan ($P < .05$) using navigation.

Conclusions: Accuracy and precision for implant placement were achieved using dynamic navigation. The use of this type of method results in smaller deviations from the planned placement compared with FH approaches.

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Conflict of Interest Disclosures: Dr Block and Dr Cullum own stock in X-Nav Technologies, LLC. Dr Emery is Chief Medical Officer of X-Nav Technologies LLC and has an equity interest in the company. Mr Ali Sheikh is employed by X-Nav Technologies, LLC.

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Static or Dynamic Navigation for Implant Placement—Choosing the Method of Guidance

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The purpose of the present report is to contrast and compare 2 methods of dental implant placement. One method uses computed tomography data for computer-aided design and computer-aided manufacturing to generate static guides for implant placement. The second method is a dynamic navigation system that uses a stereo vision computer triangulation setup to guide implant placement. A review of the published data was performed to provide evidence-based material to compare each method. Finally, the indications for each type of method are discussed.

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Clinical Problem

Dental implants need to be placed accurately at the proper depth, angulation, and crestal position. The traditional methods to place implants have used free hand or limited guidance from laboratory-fabricated stents. The use of a static, computed tomography (CT)-generated guide stent with a coordinated system of specified drilling can result in less than 2 mm crestal and apical deviation from the plan and an angulation error of less than 5°.[1-8] Freehand methods for implant placement result in significantly more error compared with navigation methods.[7] CT-generated static stents have workflow time and cost considerations. Dynamic navigation uses a time-effective method to accurately place implants with equivalent implant placement error. The question for the clinician is when to use a static system or a dynamic navigation system.

The costs of using CT-generated static stents include the cost of the software and the cost for fabrication of the CT-generated guide stent. The costs for the dynamic navigation system include the navigation computer system, including the arrays. Recurring costs include the cost of the patient-specific clips, although that cost is relatively inexpensive.

Why should clinicians consider static or dynamic navigation? Navigation can result in accurate depth control and should decrease the risk of damage to the inferior alveolar nerve. Navigation also allows for flapless or limited flap elevation, resulting in less postoperative morbidity to the patient. Navigation with virtual implant placement provides accurate spacing and angulation of the implants compared with the use of free-hand approaches. Virtual implant planning and navigated placement can ensure appropriate implant angulation and depth for esthetic situations. The use of virtual implant planning and subsequent navigation also allows for prosthetic and surgical collaboration with precise planning and accurate orchestration of the plan to achieve a high level of patient-specific results. However, both static and dynamic navigation systems have limitations, as we discuss.

Static Guides

A static system uses CT-generated computer-aided design and computer-aided manufacturing to create stents, with metal tubes, and a surgical system that uses coordinated instrumentation to place implants using the guide stent (Fig 1). The implant position is dependent on the stent without the ability to change the implant position (Fig 2). "Static" in this sense is synonymous with a predetermined implant position without real-time visualization of the implant preparation site

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CLINICAL ORAL IMPLANTS RESEARCH

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Accuracy of a novel prototype dynamic computer-assisted surgery system

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Key words: accuracy, computer aided, computer guided, dental implant, navigation, static guide, stereolithographic guide

Abstract

Objectives: To implement and evaluate the accuracy of a prototype dynamic computer-assisted surgery (CAS) system for implant osteotomy preparation and compare its accuracy vs. three commercial static CAS systems and the use of an acrylic stent.

Material and methods: Eight osteotomies were prepared in radiopaque partially edentulous mandible and maxilla typodonts. After cone-beam CT acquisition, DICOM files were imported into a prototype dynamic, and three static CAS systems (NobelClinician, Simplant, and CoDiagnostiX). Implant placements were planned to replicate the existing osteotomies and respective guides were requisitioned, along with one laboratory-made acrylic guide. The eight osteotomies per jaw were transferred to one typodont pair mounted in a manikin in a clinical setting and the process was repeated for four additional pairs. The 80 (two jaws × eight holes × five pairs) osteotomies were filled with radiopaque cement in-between the testing series. Three clinicians experienced with the use of the static CAS softwares used in this study prepared each 400 (80 holes × five modalities) osteotomies. One clinician repeated the experiment twice, resulting in a total of 2000 (five clinicians × 400) osteotomies. The lateral, vertical, total, and angular deviations of the actual vs. the original osteotomies in the master typodonts were measured using stereo optical tracking cameras. Linear regression statistics using generalized estimating equations were used for comparisons between the five modalities and omnibus chi-square tests applied to assess statistical significance of differences.

Results: The prototype dynamic CAS system was as accurate as other implant surgery planning and transfer modalities. The dynamic and static CAS systems provide superior accuracy vs. a laboratory-made acrylic guide, except vertically. Both dynamic and static CAS systems show on average <2 mm and 5 degrees error. Large deviations between planned and actual osteotomies were occasionally observed, which needs to be considered in clinical practice.

Conclusions: The prototype dynamic CAS system was comparably accurate to static CAS systems.

Implant-retained prostheses are today a treatment modality with a highly predictable outcome (Pjetursson et al. 2007). Poor implant positioning, however, compromises esthetics and function and increases the risk for biomechanical overload. An important premise for the long-term success of implant supported prosthetic restorations is proper implant position. Presurgical planning combined with use of a surgical guide during the placement of dental implants is therefore encouraged. Surgical guide techniques based on new computer technologies enable three-dimensional image reconstructions and interactive therapy planning, the latter leading to fabrication of surgical guides derived from computer tomography (CT) and computer-assisted surgery (CAS) (Fortin et al. 1995).

Static CAS modalities offer a reliable transfer of the planned implant locations. The intra-operative handling of surgical guides is uncomplicated and there is relatively easy co-ordination of procedures between guide planning, manufacturing and surgical application without the need for additional expensive equipment. However, there are also some limitations. The stability of the surgical guides, which are placed on a few remaining teeth, directly on the mucosa or the crest of the bone, is critical. Placement of implants in the posterior zone may also present a problem if the opposing dentition limits the space to insert and use the surgical guide. (Jung et al. 2009; Schneider et al. 2009; de Almeida et al. 2010; D'Haese et al. 2012; Hultin et al. 2012; Van Assche et al. 2012).

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Navigation Surgery for Dental Implants: Assessment of Accuracy of the Image Guided Implantology System

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Purpose: The purpose of this study is to assess the accuracy of the navigation provided by the Image Guided Implantology system (DenX Advanced Dental Systems, Moshav Ora, Israel), which was designed to guide the surgeon in the placement of dental implants.

Materials and Methods: Seven jaw models incorporating special ceramic spheres were imaged by dental computerized tomography. The coordinates of these reference ceramic markers were calculated by the Image Guided Implantology and compared with their actual position coordinates as identified on the computed tomography image.

Results: The overall mean spatial navigation error was 0.35 ± 0.14 mm. The 1-tailed probability of any single measurement exceeding 0.75 mm was less than 0.003, and that exceeding 1 mm was less than 0.0001.

Conclusion: The Image Guided Implantology system provides highly accurate navigation with less than 0.75 mm error, which is acceptable in dental implantology. The accurate reporting of the exact position of the drilling bur should minimize the potential risk of damage to critical anatomic structures. The accurate intraoperative navigation allows the surgeon to precisely transfer the presurgical plan to the patient.

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Computerized navigation systems offer intraoperative guidance of the surgical instruments based on a presurgical plan. This technology was implemented in neurosurgery and in orthopedic and ear, nose, and throat surgery to facilitate minimally invasive procedures.[1,2] In dental implantology, this technology has been suggested to minimize potential risk of damage to critical anatomic structures.[3]

Surgical navigation systems possess tracking ability with an accurate imaging interface. Optical tracking systems, which are the most commonly used, utilize an infrared camera detector to track surgical instruments that are equipped with infrared light emitters. The position of the surgical probe is continuously related to the imaging data of the patient to provide imaging navigation ability. This is accomplished by the establishment of an accurate interface between the computerized tomography (CT) data and the actual surgical field. Special reference (fiducial) markers are present in the surgical field, are readily identifiable on the CT image, and serve to establish this essential interface.

The navigation of this specialized Image Guided Implantology (IGI; DenX Advanced Dental Systems, Moshav Ora, Israel) system is based on optical input and is designed to provide intraoperative navigation in the placement of dental implants (Fig 1). The den-

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Computer-Aided Navigation in Dental Implantology: 7 Years of Clinical Experience

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Purpose: This long-term study gives a review over 7 years of research, development, and routine clinical application of computer-aided navigation technology in dental implantology. Benefits and disadvantages of up-to-date technologies are discussed.

Materials and Methods: In the course of the current advancement, various hardware and software configurations are used. In the initial phase, universally applicable navigation software is adapted for implantology. Since 2001, a special software module for dental implantology is available. Preoperative planning is performed on the basis of prosthetic aspects and requirements. In clinical routine use, patient and drill positions are intraoperatively registered by means of optoelectronic tracking systems; during preclinical tests, electromagnetic trackers are also used.

Results: In 7 years (1995 to 2002), 55 patients with 327 dental implants were successfully positioned with computer-aided navigation technology. The mean number of implants per patient was 6 (minimum, 1; maximum, 11). No complications were observed; the preoperative planning could be exactly realized. The average expenditure of time for the preparation of a surgical intervention with navigation decreased from 2 to 3 days in the initial phase to one-half day in clinical routine use with software that is optimized for dental implantology.

Conclusions: The use of computer-aided navigation technology can contribute to considerable quality improvement. Preoperative planning is exactly realized and intraoperative safety is increased, because damage to nerves or neighboring teeth can be avoided.

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ENDODONTICS

Computer-aided dynamic navigation: a novel method for guided endodontics

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Objectives: To investigate the novel use of computer-aided dynamic navigation for guided endodontics. **Method and materials:** Dental casts were fabricated from sets of extracted human teeth. A cone beam computed tomography (CBCT) scan of each cast, with a molded thermoplastic stent and a radiographic marker attached, was obtained and imported into the planning software of a dynamic navigation implant surgery system. Simulating implant surgery but for guided endodontics, the drilling entry point, angle, pathway, and depth of virtual implants were planned for 29 selected teeth. The radiographic marker was replaced with a jaw tag and mounted in a phantom head. A drill tag was attached to the drill handpiece. Following calibration, guided by the stereoscopic motion-tracking camera via the tags and images on a computer monitor providing real-time dynamic plus visual intraoperative feedback, the handpiece was aligned accordingly and endodontic access cavity preparation carried out. Successful root canal location was confirmed using periapical radiographs and CBCT. **Results:** Conservative access cavities were achieved and all the expected canals were successfully located in 26 teeth (n = 29). Due to tracking difficulties, only one canal was located in two maxillary second molars; in a maxillary first molar, only two canals were located and the access preparation for the third canal was misaligned and off-target. **Conclusions:** The results of this study demonstrate the potential of using computer-aided dynamic navigation technology in guided endodontics in clinical practice.
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Key words: access cavity, cone beam computed tomography, dynamic navigation, endodontics, guided endodontics

In nonsurgical root canal treatment, the access cavity should be prepared according to access requirements whilst avoiding unnecessary and destructive tooth tissue removal.[1] Access cavity preparation that involves both the mesial and distal marginal ridges can reduce cuspal stiffness by up to 63%.[2] Therefore, especially with the advent of "minimally invasive endodontics,"[3,4] access cavities should be kept as conservative as possible. Instead of the traditional endodontic cavity, conservative/contracted endodontic cavity and ultraconservative "ninja" endodontic cavity have been promoted.[5] However, there are a number of clinical scenarios that make the conservative aim challenging. For example, in order to try to locate the root canal system of teeth with calcified coronal pulp space or sclerosed canals, increasing amounts of tooth tissue may need to be removed, compromising structural integrity and risking perforation. In everyday clinical practice, any strategy or guidance that allows the preparation of a minimal access cavity, with decreased risk of iatrogenic damage, and preserves structural integrity while meeting all the access requirements, is to be welcomed.

The concept of utilizing some form of guidance system has been an area of interest for some time in implant surgery. Correct positioning is crucial so that implants are placed at the desired angulation and depth. The introduction of cone beam computed tomography (CBCT) has transformed treatment planning so that the ideal implant position can be determined preoperatively, while taking into consideration important surrounding anatomical structures.[6] Consequently, techniques have been developed in an attempt to improve the accuracy of implant surgery by using guidance based on CBCT data.

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CASE REPORT/CLINICAL TECHNIQUES

Guided Endodontic Access in a Maxillary Molar Using a Dynamic Navigation System

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ABSTRACT

The treatment of calcified root canals is challenging in endodontic practice. A 63-year-old man was referred to the postgraduate endodontic clinic at the University of Maryland School of Dentistry, Baltimore, MD, for the treatment of tooth #3. Because of the patient's history of head and neck radiation and the high risk of developing osteoradionecrosis, a nonsurgical endodontic approach was found to be the most reasonable treatment option despite the questionable prognosis of the tooth. During the endodontic treatment, the distobuccal canal appeared to be partially calcified and was not possible to be located freehand even with use of the dental operating microscope and cone-beam computed tomographic approximated approach. Therefore, the dynamic navigation system using the X-Guide system (X-Nav technologies, LLC, Lansdale, PA) was used, which allowed for the successful location of the canal. Conventional endodontic treatment was completed following standardized instrumentation, irrigation, and obturation. Details on how to use the dynamic navigation system are described including its advantages, disadvantages, and limitations. *(J Endod 2020;■:1–5.)*

KEY WORDS

Calcification; dynamic navigation system; guided endodontics; pulp canal obliteration; X-guide

SIGNIFICANCE

The DNS is a promising technology developed to dynamically guide drills based on information generated from the patient's CBCT scan. This case report shows the potential of this system to be applied in nonsurgical endodontics for access cavity preparation of severely calcified canals.

Access to calcified canals presents a significant and challenging procedural step during root canal therapy. Regardless of the etiologic factors that might result in pulp canal obliteration, histologic specimens of teeth with pulp canal obliteration usually present a persisting narrow root canal[1], which is difficult to locate in many circumstances. With an increased risk of catastrophic mishaps such as perforation, much care must be exercised during access cavity preparation, canal negotiation, and instrumentation of these canals. Application of the dental operating microscope (DOM) and cone-beam computed tomographic (CBCT) imaging have been very helpful in treating several calcified cases[2–4]. However, even with these advancements, excessive dentin removal or even perforation can still occur in many occasions that might negatively impact tooth survival[5]. Guided endodontics is a relatively new approach using a fabricated template to guide a dental bur toward the root canal. This results in a conservative apically extended access cavity preparation for locating obliterated root canals[6]. Despite the high accuracy demonstrated by many studies[7–9], static guides have limitations, including the difficulty or inability to be used in posterior teeth because of limited interocclusal space. The dynamic navigation system (DNS) is an alternate approach adopted from implant dentistry and has been used in endodontics for surgical and nonsurgical treatment[8]. DNS integrates spatial positioning technology and CBCT imaging using an optical tracking system controlled by a dedicated computerized interface. A clinical real-time navigation guides the user to drill into the targeted position according to the output of a preoperative plan[10]. The X-Guide (X-Nav Technologies, LLC, Lansdale, PA) is an accurate system developed to offer clinicians an affordable way to virtually plan implants and insert the fixture with high accuracy with real-time 3-dimensional (3D) control. A recent *in vitro* study on a natural tooth model showed that this system is more accurate and more efficient than the freehand technique in locating calcified canals and can help clinicians avoid catastrophic mishaps during access preparation in calcified teeth[11]. To our knowledge, this is the first case report that presents the use of the X-Guide DNS for canal location in a calcified maxillary molar root. The aim of this report was to show the efficacy of this technique as well as its limitations for managing complex, clinically calcified root canals in which conventional endodontic treatment using DOM and the CBCT approximated method did not allow canal location.

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Outcome of Endodontic Surgery: A Meta-analysis of the Literature—Part 1: Comparison of Traditional Root-end Surgery and Endodontic Microsurgery

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Abstract

Introduction: The aim of this study was to investigate the outcome of root-end surgery. The specific outcome of traditional root-end surgery (TRS) versus endodontic microsurgery (EMS) and the probability of success for comparison of the 2 techniques were determined by means of meta-analysis and systematic review of the literature. **Methods:** An intensive search of the literature was conducted to identify longitudinal studies evaluating the outcome of root-end surgery. Three electronic databases (Medline, Embase, and PubMed) were searched to identify human studies from 1966 to October 2009 in 5 different languages (English, French, German, Italian, and Spanish). Relevant articles and review papers were searched for cross-references. Five pertinent journals (*Journal of Endodontics, International Endodontic Journal, Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics, Journal of Oral and Maxillofacial Surgery, International Journal of Oral and Maxillofacial Surgery*) were individually searched back to 1975. Three independent reviewers (S.S., M.K., and F.S.) assessed the abstracts of all articles that were found according to predefined inclusion and exclusion criteria. Relevant articles were acquired in full-text form, and raw data were extracted independently by each reviewer. Qualifying papers were assigned to group TRS or group EMS. Weighted pooled success rates and relative risk assessment between TRS and EMS were calculated. A comparison between the groups was made by using a random effects model. **Results:** Ninety-eight articles were identified and obtained for final analysis. In total, 21 studies qualified (12 for TRS [n = 925] and 9 for EMS [n = 699]) according to the inclusion and exclusion criteria. Weighted pooled success rates calculated from extracted raw data showed 59% positive outcome for TRS (95% confidence interval, 0.55–0.6308) and 94% for EMS (95% confidence interval, 0.8889–0.9816). This difference was statistically significant ($P < .0005$). The relative risk ratio showed that the probability of success for EMS was 1.58 times the probability of success for TRS. **Conclusions:** The use of microsurgical techniques is superior in achieving predictably high success rates for root-end surgery when compared with traditional techniques *(J Endod 2010;36:1757–1765)*

Key Words

Amalgam, apicoectomy, endodontic microsurgery, IRM, meta-analysis, MTA, outcome, root-end surgery, success, SuperEBA, systematic review

Endodontic surgery is a dental procedure to treat apical periodontitis in cases that did not heal after nonsurgical retreatment or, in certain instances, primary root canal therapy (1). This might include situations with persistent or refractory intracanal infection after iatrogenic changes to the original canal anatomy (2) or microorganism in proximity of the constriction (3) and the apical foramen (4). Other reasons might be found in extraradicular infection, such as bacterial plaque on the apical root surface (5) or bacteria within the lesion itself (6–9).

Few dental techniques have been substantially transformed as has endodontic surgery. Various techniques were suggested to make the procedure easier to execute, safer for the patient, and more predictable (10). For many years, the state of the art was the traditional approach with surgical burs and amalgam for root-end filling (11–13). Modern techniques incorporate the use of ultrasonic tips and more biocompatible filling materials such as intermediate restorative material (IRM), SuperEBA, and mineral trioxide aggregate (MTA) (14). Endodontic microsurgery (EMS) is the most recent step in the evolution of periradicular surgery, applying not only modern ultrasonic preparation and filling materials but also incorporating microsurgical instruments, high-power magnification and illumination (15).

Although many studies have been published that advocate the use of modern approaches, the traditional techniques are still widely used in the oral surgery and maxillofacial surgery community, and the success rates of modern techniques are debated (16, 17). In 2008, a survey from the Netherlands reported the use of amalgam by oral surgeons as a root-end filling material at 35%, second only to IRM (18). MTA was only used in 2.6%, although it was recommended as the most biocompatible root-end filling material available to date (15, 19). Several reviews and meta-analyses were published on the outcome of endodontic surgery, but they failed to identify cumulative success rates for different techniques (10, 14, 20). One recent meta-analysis addressed the outcome of endodontic surgery with ultrasonic root-end preparation and modern filling materials, but it did not clearly distinguish between

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Reliability of Implant Placement With Stereolithographic Surgical Guides Generated From Computed Tomography: Clinical Data From 94 Implants

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Background: Dental implant placement requires precise planning with regard to anatomic limitations and restorative goals. The aim of this study was to evaluate the match between the positions and axes of the planned and placed implants using stereolithographic (SLA) surgical guides.

Methods: Ninety-four implants were placed using SLA surgical guides generated from computed tomography (CT) between 2005 and 2006. Radiographic templates were used for all subjects during CT imaging. After obtaining three-dimensional CT images, each implant was virtually placed on the CT images. SLA surgical guides, fabricated using an SLA machine with a laser beam to polymerize the liquid photo-polymerized resin, were used during implant placement. A new CT scan was taken for each subject following implant placement. Special software was used to fuse the images of the planned and placed implants, and the locations and axes were compared.

Results: Compared to the planned implants, the placed implants showed angular deviation of 4.9° ± 2.36°, whereas the mean linear deviation was 1.22 ± 0.85 mm at the implant neck and 1.51 ± 1 mm at the implant apex. Compared to the implant planning, the angular deviation and linear deviation at the neck and apex of the placed maxillary implants were 5.31° ± 0.36°, 1.04 ± 0.56 mm, and 1.57 ± 0.97 mm, respectively, whereas corresponding figures for placed mandibular implants were 4.44° ± 0.31°, 1.42 ± 1.05 mm, and 1.44 ± 1.03 mm, respectively.

Conclusion: SLA surgical guides using CT data may be reliable in implant placement and make flapless implant placement possible. *J Periodontol 2008;79:1339-1345.*

KEY WORDS

Computed tomography; dental implants.

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Compared to conventional flap surgery, flapless implant placement, which is a less time-consuming, more esthetic, and less invasive technique to restore any type of edentulism, has become increasingly popular.[1-3] Although flapless implant surgery has numerous advantages, including preservation of soft tissue architecture and hard tissue volume at the region, decreased surgical time, improved patient comfort, and accelerated recuperation, the approach has some disadvantages.[1-3] Some of these include the surgeon's inability to visualize anatomic landmarks and vital structures, the increased risk for malposed angle or depth of implant placement, and a decreased ability to contour osseous topography when needed to facilitate restorative procedures.

To eliminate the drawbacks mentioned above and improve the outcome of flapless implant surgery, more advanced diagnostic imaging (i.e., computed tomography [CT]), has been suggested for presurgical planning of the implants.[1,4-6] CT imaging allows the surgeon to visualize cross-sectional, axial, and panoramic views of the patient's jaws for more accurate planning of implant placement. When using radiopaque material, it is possible to visualize soft and hard tissue dimensions on the CT images in relation to the surgical guide.[7] This presurgical CT image is often used

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CLINICAL ORAL IMPLANTS RESEARCH

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Factors influencing transfer accuracy of cone beam CT-derived template-based implant placement

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Key words: computer-aided implant planning, cone-beam computed tomography, dental implants, determining factors, surgical template

Abstract

Objectives: The aim of the present investigation was the analysis of the factors presumptively affecting the accuracy outcome of cone-beam computed tomography (CBCT)-derived laboratory-based surgical guides for implant placement in partially edentulous patients.

Materials and methods: In 52 partially edentulous patients a total of 132 implants were placed following CBCT diagnostics with the aid of laboratory-fabricated, tooth-borne templates. Based on the image fusion technique measurements were done to calculate linear and angular deviations between virtually planned and placed implants. The implant sites were stratified according to four factors that presumably may influence the transfer accuracy: (i) type of arch (maxilla/mandible), (ii) kind of template (single-tooth gap/interrupted dental arch/shortened dental arch/reduced residual dentition), (iii) surgical technique (flapless/open flap), (iv) number of sleeve-guided site preparation steps (fully guided placement/freehand placement/freehand final drilling). The data were analyzed using analysis of variance and the Bonferroni test.

Results: The transfer accuracy of shoulder level, apex level, and angulation was similar for maxilla and mandible as well as for flapless and open flap approach. The differences were small in magnitude and reached no or only a borderline statistical significance. At implant sites in the reduced residual dentition group, the discrepancies were more pronounced than in the single-tooth gap group, whereas no significant differences could be determined between free ending templates in the shortened dental arch and bilateral anchored templates in the interrupted dental arch. Implant placement through the guide allowed a more accurate implementation of the virtual plan to the surgical site than freehand insertion or freehand final drilling.

Conclusion: CBCT-derived laboratory-based surgical templates enabled an implant placement in the cancellous maxilla as well as flapless procedures without compromising the transfer accuracy. The number and distribution of the remaining teeth as well as the number of sleeve-guided implant site preparation steps influenced the extent of deviation that can be achieved in partial edentulism.

Restoration driven implant planning and placement requires precise assessment of the surgical site and the prospective prosthetic restoration. To achieve a supra-structure-orientated implant positioning various types of surgical guides have been developed and used in implant dentistry. Insertion of implants by the aid of (CB)CT-derived surgical templates enables clinicians to address considerations for the most optimal position prior to the surgery and the prosthetic work.

Template-guided implant surgery requires several preoperative steps, starting with fabrication of a radiographic template, the cone-beam computed tomography (CBCT) acquisition with the template in position, computer-assisted implant planning and ending in fabrication, and use of a surgical guide with corresponding sleeves closely matched to the diameter of the drills and/or implants. With such a complex treatment planning sequence with many potential sources of error, an important issue is the question of possible deviations between the preoperative plan and the postoperative implant location. Several articles were recently published on the accuracy of computer-assisted template-guided implant surgery concepts (Van Steenberghe et al. 2002; Sarment et al. 2003; Van Assche et al. 2007; Ersoy et al. 2008; Kalt & Gehrke 2008; Ruppin et al. 2008; Vercruyssen et al. 2008; Behneke et al. 2009; Horwitz et al. 2009; Jung et al. 2009; Ozan et al. 2009; Schneider et al. 2009; Valente et al. 2009; D'haese et al. 2010; Pettersson et al. 2010; Vasak et al. 2011). Two different techniques have

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Evaluation of the difference in accuracy between implant placement by virtual planning data and surgical guide templates versus the conventional free-hand method – a combined in vivo – in vitro technique using cone-beam CT (Part II)

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SUMMARY. Purpose: **The purpose of this study was to assess the accuracy of implant placement after virtual planning of implant positions using cone-beam CT data and surgical guide templates, and to match the results with those achieved with the conventional free-hand method.** Materials and methods: **Twenty-three implants were placed in 10 patients with a Kennedy Class II with 3-dimensional (3-D) planned surgical guide template. Manual implantation was performed in anatomical casts of the same patients by a prosthodontist and a maxillo-facial surgeon. Postoperative images of casts were superimposed onto the preoperative image of virtual planned ideal position of the implant.** Results: **The 3-D surgical guide template produced significantly smaller variation between the planned and actual implant positions at the implant shoulder (0.9 mm (0–4.5)) and apex (0.6–0.9 mm (0.0–3.4)) compared with the free-hand implantation (2.4–3.5 mm (0.0–7.0); $p = 0.000$ and 2.0–2.5 mm (0.0–7.7); $p = 0.002$). Accuracy of axis was also significantly improved.** Conclusions: **Accuracy of implant placement after virtual planning of implant position using cone-beam CT data and surgical templates is high and significantly more accurate than free-hand insertion. The demonstrated method of superimposing radiographic images of postoperative casts and virtual planning images is a useful method, which allows reduced patient radiation exposure.**

Keywords: **dental implantation, image processing, computer-assisted, three-dimensional, patient care planning**

INTRODUCTION

The use of computer-aided surgical systems for dental implant bed preparation and implant placement results in an average precision within 1 mm of implant position and within 5° of deviation for implant inclination (*Besimo* et al., 2000; *Sarment* et al., 2003; *Schneider* et al., 2004; *Widmann* et al., 2005; *Van Assche* et al., 2007; *Ersoy* et al., 2008). Recently published in vitro and in vivo studies indicate no significant differences between the different computer-aided surgery systems in dental implantology (*Wittwer* et al., 2007). Additionally, there is no significant difference in accuracy between the use of surgical templates or intraoperative navigation using optical tracking (*Ruppin* et al., 2008).

Precision and accuracy of computer-based or –supported implant placement is valuable only if an exact transfer to the intraoral anatomy is possible. The use of surgical templates requires good intraoperative stability of the guide. Fixed intraoral reference points can effectively improve precision in cases of unilateral bone-supported and non-tooth-supported guides (*Di Giacomo* et al., 2005; *Holst* et al., 2007).

Most currently published studies have evaluated the accuracy of computer-aided surgical systems. Only a few consider the clinical effectiveness of these systems in comparison with the conventional free-hand method. It has been reported that the accuracy of free-hand implantation is sufficient for most clinical situations (*Brief* et al., 2005); it is also reported that computer-aided surgical systems reduce the risk of damage to adjacent structures (*Fortin* et al., 2003; *Suzuki and Suzuki*, 2008). Accurate presurgical planning also permits implementation of restorative goals (*Lal* et al., 2006; *Nickenig and Eitner*, 2007; *Katsoulis* et al., 2008).

The purpose of this study was to assess the difference in accuracy between implant placement after virtual planning using cone-beam CT data and surgical guide templates versus the conventional free-hand method.

The applied method of evaluating planned and achieved implant position, with elimination of postoperative radiation exposure, was described by *Nickenig* and *Eitner* (submission part I). It was hypothesized that this new evaluation technique provided results similar to those provided by comparison of pre- and postoperative CT imagine, i.e. confirming a high rate of precision for

Correlation Between Bone Density and Angular Deviation of Implants Placed Using CT-Generated Surgical Guides

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Background: The aim of this study was to evaluate the correlation between the density of bone where implants were placed and the angular deviations that occurred between the virtually planned and actually placed implants using 2 different stereolithographic surgical guides.

Methods: The study population consisted of 54 patients who received 216 implants. Computed tomography machine was used for preoperative evaluation of the jawbone for implant therapy as well as determination of the bone density values (Hounsfield units [HU]) of the implantation site. All implant sockets were prepared using 2 different types of stereolithographic surgical guide. Ninety-four implants were installed using the surgical guides (Stentcad Beyond, Ay-Design; Kos-gep, ODTU, Ankara, Turkey) in the mouth, whereas 122 implants were placed after the surgical guides (Stentcad Classic; Kos-gep, ODTU) were removed.

Results: The mean bone densities of maxilla and mandible were 561.36 (SD, 229.46) HU and 890.63 (SD, 361.85) HU, respectively. The mean angular deviations between planned and placed implants using Stentcad Classic and Stentcad Beyond surgical guides were 5.32 (SD, 1.96) degrees and 3.73 (SD, 1.14) degrees, respectively. Highly negative correlation was found between the bone density of the placed implant sites and angular deviations in the group in whom implants were installed with freehand.

Conclusions: The lower bone density values have resulted in the greater angular deviations in the group, in whom the implants were placed after the surgical guides were removed. This deviation might have been derived from the freehand placement of the implants and the poor quality of the bone.

Key Words: Implants, bone density, computerized tomography, surgical guide, Hounsfield unit

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The study was presented in the seventh Asian Congress of Oral Maxillofacial Radiology, which was held in Nara, Japan, and awarded with the best oral presentation award (Yoshida Award).
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Dental implants have become a favorable option in the treatment of edentulous patient in the last decade. The successful outcome of implant osseointegration involves patient-originated and procedure-dependent variables. The quality of the bone and the type of surgical procedure are of primary factors for long-term survival of dental implants.[1]

Various classification methods were introduced for the evaluation of bone quality as the mechanical behavior of the bone is a crucial factor for osseointegration.[2–4] Lekholm and Zarb[5] classified bone density into 4 types based on the amount of cortical versus cancellous bone in a given area of the alveolar process observed on a panoramic radiograph. Subsequently, Misch,[5] based on the tactile sense of the surgeon placing the implant, has characterized 4 bone density classes.

Bone quality and quantity are generally estimated from radiographs or during implant placement.[6] In most studies, classification of bone type was based on the subjective evaluation of the clinician.[7] Computed tomography (CT) is primarily used for objective preoperative assessment of the bone with quantitative data, evaluating the relative distribution of compact[8] and cancellous[9] bone. Bone density can be evaluated using Hounsfield units (HU), which are directly related to tissue attenuation coefficients.[6] Recent studies have shown that the bone density value is an important parameter for a successful implant.[10–12]

Research in the field of oral implantology has led to refinements resulting in highly successful and predictable restorative options for partially as well as completely edentulous patients; however, improper implant placement can have a profound and often detrimental effect on the long-term predictability and success of the implant-supported prosthesis.[13,14] It has also been suggested in previous studies that implants be positioned parallel to the path of insertion of planned prosthesis and as perpendicular to the occlusal plane as possible to minimize the bending moments.[15,16]

Although the ideal placement of dental implants should be determined by prosthetic parameters, the exact positioning of the implant with respect to location and angulation is often difficult.[17] Moreover, aesthetic and functional planning is complex and requires a professional experience to detect patient expectances in relation to the alternatives for final results.[18] Problems may arise especially in complete-arch patients with multiple fixtures and in partially edentulous patients in which alignment is difficult or in grafted jaws.[19]

To reduce alignment problems, numerous types of radiographic and surgical templates and techniques have been proposed. A few studies emphasized radiographic scanning and surgical templates.[20,21] A number of articles introduced templates for the dual use of the first radiologic planning and then guidance for the surgical implant placement.[18,22] In vitro,[23,24] ex vivo,[25,26] and clinical studies[27–30] showed the efficiency of stereolithographic surgical guides used for

Prognostic Factors of Clinical Outcomes in Endodontic Microsurgery: A Prospective Study

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Abstract

Introduction: This prospective study examined the potential prognostic factors of endodontic microsurgery and compared the predictors of an isolated endodontic lesion with those of both an isolated endodontic lesion and an endodontic-periodontal lesion. **Methods:** Data were collected from the Microscope Center of the Department of Conservative Dentistry at the Dental College of Yonsei University, Seoul, Korea, between March 2001 and March 2011. A total number of 584 teeth were included, and all clinical procedures were performed by a single operator (E.K.). The evaluation was performed at least 1 year after surgery. For statistical analysis of the predisposing factors, the chi-square test and logistic regression were performed. **Results:** Of the 584 cases treated, 431 cases came for recall after a period of at least 12 months. Sex (female), tooth position (anterior), arch type (maxilla), and lesion type (isolated endodontic lesion) were found to have a positive effect on surgical outcome. With regards to isolated endodontic lesions, the tooth position (anterior), arch type (maxilla), and type of restoration (single/splinted crown, short bridge, and removable partial denture abutment) were found to be pure positive predictors. **Conclusions:** In endodontic microsurgery, it is likely that preoperative factors, particularly the tooth position and arch type, have a greater influence on the healing outcome than intra- and postoperative factors. *(J Endod 2013;39:1491–1497)*

Key Words

Endodontic microsurgery, healing outcome, prognostic factors, prospective clinical study, tooth position

Before the advent of surgical operating microscopes, the success rates of traditional endodontic surgery ranged from 43% to 75% (1), which is lower than those of nonsurgical retreatments (2). However, root-end surgery has changed radically over the last 20 years with the implementation of microsurgical techniques and the use of advanced equipment. In recent years, endodontic microsurgery including the use of high-power illumination and magnification (10× and higher), ultrasonic root-end preparation, and biocompatible root-end filling materials has produced favorable outcomes in the 90% success rate range (1, 3).

Several studies have reported on the prognostic factors for apical surgery, which are not classified according to the type of surgical technique such as traditional root-end surgery, contemporary root-end surgery, and endodontic microsurgery (4–6). Numerous authors have analyzed the effects of individual variables on the outcome of endodontic surgery. Most predictable preoperative prognostic factors in many studies include the length and quality of existing root filling, the presence of preoperative lesion, the presence of post and the lesion size. The intraoperative factors include the placement of root-end filling, the root-end preparation methods, the root-end filling materials, and the operator's skill. The postoperative factors include the apical and coronal seal (4–8).

In the past decade, many studies have reported on the clinical outcomes of endodontic microsurgery (3, 9, 10). However, there are only a few reports related to the prognostic factors of endodontic microsurgery. Von Arx et al (10) evaluated the influence of various predictors on healing outcome 1 year after endodontic microsurgery with 194 teeth (10). Using logistic regression, the pain at initial examination ($P = .04$) was the only predictor reaching significance. In another study by von Arx et al (11) that assessed the 5-year outcome and its predictors in a cohort for which the 1-year outcome was reported, 2 significant outcome predictors were found: a mesial-distal bone level at ≤3 mm versus >3 mm from the cementoenamel junction (78.2% vs 52.9%, $P < .02$) and root-end filling with ProRoot MTA (Dentsply, Tulsa, OK) versus Super EBA (Harry J. Bosworth, Skokie, IL) (86.4% vs 67.3%, $P < .004$).

In our previous retrospective study (12), the potential prognostic factors for endodontic microsurgery were sex (female), tooth position (anterior), lesion type (isolated endodontic lesion) and root-end filling material (ProRoot MTA and Super EBA). When periodontally involved lesions were excluded, an isolated endodontic lesion might reduce the effects of many variables. The tooth position (anterior) was found to be a pure predictor of an endodontic lesion affecting the clinical outcome. However, prognostic factors have been rarely reported for endodontic microsurgery, and more research is needed. This prospective study examined the potential prognostic

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Comparison of Mineral Trioxide Aggregate and iRoot BP Plus Root Repair Material as Root-end Filling Materials in Endodontic Microsurgery: A Prospective Randomized Controlled Study

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Abstract

Introduction: This prospective randomized controlled study evaluated the clinical and radiographic outcome of endodontic microsurgery when using iRoot BP Plus Root Repair Material (BP-RRM; Innovative BioCeramix Inc, Vancouver, BC, Canada) or mineral trioxide aggregate (MTA) as the retrograde filling material and analyzed the relationship between some potential prognostic factors and the outcome of the surgery. **Methods:** By using strict inclusion and exclusion criteria, 240 teeth were successfully enrolled and randomly and equally allocated to either the MTA or BP-RRM treatment group. A standardized surgical procedure was performed by a single operator. The patients were followed up at 1 week, 3 months, 6 months, and 12 months; follow-up included clinical and radiographic examination. Clinical and radiographic evaluations acquired at the 12-month follow-up were taken as the primary outcome. For the identification of prognostic factors, the dichotomous outcome (success vs failure) was taken as the dependent variable. **Results:** A total of 158 teeth were analyzed at the 12-month follow-up, including 87 teeth in the MTA group and 71 teeth in the BP-RRM group. The success rate in the MTA and BP-RRM groups was 93.1% (81/87 teeth) and 94.4% (67/71 teeth), respectively ($P > .05$). Three significant outcome predictors were identified: quality of root filling ($P < .05$), tooth type ($P < .05$), and size of the lesion ($P < .05$) **Conclusions:** These results suggest that BP-RRM is comparable with MTA in clinical outcome when used as root-end filling materials in endodontic microsurgery. (*J Endod 2017;43:1–6*)

Key Words

endodontic microsurgery, iRoot BP Plus Root Repair Material, mineral trioxide aggregate, randomized clinical trial, root-end filling material, success rate

Significance

Endodontic microsurgery is effective to preserve teeth with post-treatment apical periodontitis. Our study evaluated the clinical outcome of endodontic microsurgery when mineral trioxide aggregate and iRoot BP Plus Root Repair Material were used as retrograde filling material in human subjects.

Surgical intervention is required to preserve teeth with post-treatment apical periodontitis when nonsurgical treatment fails to improve the condition (1). During the last 20 years, apical surgery has undergone marked changes and evolved into endodontic microsurgery (EMS), which involves the use of state-of-the-art equipment, instruments, and more biocompatible materials (2).

For root-end filling, the ideal material should be biocompatible with host tissues, nonresorbable, antibacterial, and dimensionally stable. It should seal off the communication between the root canal system and the surrounding tissues. Furthermore, regeneration of the periodontal ligament should also be addressed (3). Because none of the materials available before 1993 possessed these ideal characteristics, in that year, mineral trioxide aggregate (MTA) (ProRoot MTA; Dentsply, Tulsa, OK) was developed and introduced. Endodontic microsurgery using ultrasonic preparation and MTA restorations has been reported to have a good success rate (ie, 94%) (4). However, MTA also has some drawbacks, including a long setting time, high material cost, low washout resistance, and difficulty in handling (5).

iRoot BP Plus Root Repair Material (BP-RRM; Innovative BioCeramix Inc, Vancouver, BC, Canada), a type of bioceramic material, has recently been introduced into clinical application to address these issues. It has been indicated for use in root-end filling as well as root reparation. BP-RRM is a ready-to-use premixed bioceramic paste with a calcium silicate composition (ie, calcium silicates, zirconium oxide, tantalum pentoxide, calcium phosphate monobasic, and filler agents). It requires the presence of water to set and harden, and it requires a minimum of 2 hours to set according to the manufacturer. It does not shrink during setting and has excellent physical properties.

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ORIGINAL ARTICLE

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Digitally planned root end surgery with static guide and custom trephine burs: A case report

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Abstract

Introduction: Apicoectomy is an endodontic surgical intervention that requires high precision. The computer-assisted static guided approach has proven to increase the precision of dental implantation in a significant manner. The authors sought to transfer this precision to root-end resection with the use of custom designed trephine burs manufactured specifically for use in targeted endodontic microsurgery.

Methods: A set of custom bone trephines were designed and manufactured, then their digital models were integrated into an already existing implant surgical planning software, in cooperation with the software developer. Apicoectomy was performed in an actual case with the help of the new system.

Results: It has become possible to plan root end removal in the virtual space and to manufacture 3D printed static surgical guides to help the execution of the surgery. A patient with persistent periapical lesion was successfully treated without complication. The 6-month follow-up found uneventful healing.

Conclusion: The presented system is a step toward a standardized digital system and workflow dedicated to guided endodontic surgery.

KEYWORDS

3D printing, apicoectomy, targeted endodontic microsurgery, static surgical guide

1 | INTRODUCTION

Apicoectomy is a routine endodontic surgical intervention, the aim of which is to surgically maintain a tooth that primarily has an endodontic lesion that cannot be resolved by conventional endodontic (re-) treatment. It is widely accepted that 3 mm of the root tip has to be removed to eliminate >90% of the ramifications and lateral canals,[1,2] in which case the chance of recurrence is minimal. In an optimal case, the cut is performed perpendicularly to the root axis. Apical and coronal deviations can both lead to suboptimal results, complications, and further recurrence. Precise targeting, therefore, is crucial. The conventional approach to such endodontic cases uses drills and relies entirely on mental navigation based on a cone-beam computer tomography (CBCT) image. While a CBCT image means considerable help, it is still very difficult to determine the exact entry point on the surface of the bone without further aids, and navigation within the bone presupposes an excellent ability to transfer a mental image into the actual patient anatomy. A general drawback of this approach, thus, is that the outcome is highly operator dependent. Complications and undesirable outcomes include missing or simply perforating the apex and/or damaging nearby anatomical structures. Minimal invasiveness is similarly important: the smaller the osteotomy, the faster the healing.[3,4]

Precision is a similarly important objective in dental implantology, given the complications associated with misplaced implants. 3D printed surgical templates to guide drills and other instruments, and

The Influence of Bone Tissue Deficiency on the Outcome of Endodontic Microsurgery: A Prospective Study

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Abstract

Introduction: This study assessed the influence of deficiencies of the periapical and marginal bone tissue on clinical outcomes after endodontic microsurgery. **Methods:** Data were collected from the Microscope Center of the Department of Conservative Dentistry at the Dental College of Yonsei University, Seoul, South Korea, between August 2004 and March 2011. In total, 199 teeth that required endodontic surgery were included in the study. During the surgical procedure, deficiencies of the periapical and marginal bone tissue were measured immediately before the flap was repositioned. The patients were recalled 6 months and 1 year after the surgical procedure to assess the clinical and radiographic signs of healing. The Student's *t* test or the Mann-Whitney *U* test and logistic regression were performed to evaluate the parameters. Significant associations between the outcome and all the evaluation parameters were analyzed using the Pearson chi-square test or the Fisher's exact test with a significance level of 0.05. **Results:** A recall rate of 67.8% (135/199 teeth) was obtained. The height of the buccal bone plate was the only significant predictor ($P = .040$) of the healing outcome, suggesting that teeth with a buccal bone plate >3 mm presented a higher success rate than teeth with a buccal bone plate that was ≤3 mm high (94.3% vs 68.8%, $P < .001$). **Conclusions:** These data suggest that a favorable prognosis can be expected when teeth are covered with a buccal bone plate that is >3 mm in height regardless of the amount of marginal bone loss. *(J Endod 2013;39:1341–1345)*

Key Words

Bone deficiency, buccal bone plate, clinical outcome, endodontic microsurgery, marginal bone loss

Successful healing after endodontic surgery depends not only on the bacteria-tight seal of the root canal system with root-end filling but also on the deficiencies of the periapical and marginal bone tissue adjacent to the lesion (1). In studies that evaluated the relationship of the healing outcome to radiographically measured preoperative lesion size, teeth with smaller lesions (≤5 mm) presented a better outcome than teeth with larger lesions (>5 mm) (2). After bone preparation, a significant correlation was found between a larger bony crypt and unsuccessful or uncertain healing (3–5). Specifically, the width of the bony crypt was found to affect the healing outcome (5). Notably, in the presence of "through and through" lesions, complete healing was observed in only 25% of cases (3).

A periodontally involved lesion is also believed to have an adverse effect on the outcome of endodontic surgery (3, 6, 7). Therefore, most studies examining the outcome of endodontic surgery exclude teeth with an apicomarginal defect or a deep probing depth greater than 7 mm (8, 9). Teeth with periodontally involved lesions present a lesser healing rate (77.5%) even when microscope-assisted regenerative techniques are applied (6). When the pathological process of periapical lesions includes the localized complete loss of marginal bone, the success rates range from 27%–37% (3, 7). The reason for this poor prognosis may be the formation of a long junctional epithelium over the dehisced root surface (3, 10, 11). Repair with long junctional epithelium is vulnerable to the dissemination of microorganisms, which may lead to the failure of endodontic surgery (12).

With traditional endodontic surgery, there is a tendency to enlarge the osteotomy toward the coronal margin, away from the apex and root resection, with an unavoidable steep bevel angle of 45°–60°. This results in the excessive removal of healthy bone around the coronal root. This may easily cause a periodontal-endodontic communication and interfere with the healing process after surgery. However, endodontic microsurgery allows for a smaller osteotomy with a shallower bevel angle. As a result, the removal of the cortical bone and root length is minimized (13). The purpose of this study was to assess the influence of deficiencies of the periapical and marginal bone tissue on the clinical outcome after endodontic microsurgery.

Methods

Case Selection and Inclusion/Exclusion Criteria

This study was approved by the Yonsei University Yonsei Dental College Institutional Review Board, Seoul, South Korea, and informed consent was acquired from

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Accuracy of 3-dimensional–printed Endodontic Surgical Guide: A Human Cadaver Study

Check for updates

Shira Ackerman, DDS,[*] Francisco Curiel Aguilera, DDS,[†] John M. Buie, DDS,[‡] Gerald N. Glickman, DDS, MS,[*] Mikhail Umorin, MS, PhD,[§] Qian Wang, PhD,[§] and Poorya Jalali, DDS[*]

Abstract

Introduction: Cone-beam computed tomographic (CBCT)-based 3-dimensional–printed surgical guides, such as those used in implant placement and orofacial surgery, allow for accurate planning and performance of surgical procedures. The objective of this study was to evaluate the accuracy of CBCT-designed surgical guides for use during endodontic surgery. **Methods:** A split-mouth design was conducted using 48 roots in a cadaver model. In the experimental group, using information from the preoperative CBCT scans and digital impressions, surgical guides were designed using Blue Sky Bio (Grayslake, IL) planning software and printed using a Form 2 3-dimensional printer (Formlabs, Somerville, MA). The guides were designed to allow for surgical access at 3 mm from the apex of each root with depth control to the lingual or palatal surface of the root. In the control group, surgical access was completed "freehand" by visually approximating measurements from the CBCT scan only. The planned and postoperative CBCT images were superimposed, and the deviation of the surgical access point from the planned target was measured using Invivo software (Anatomage, San Jose, CA). A 2-tailed *t* test and the Fisher exact test were conducted to compare the deviation in the experimental CBCT-guided group versus the control CBCT-approximated freehand group. **Results:** The mean deviation for the guided group (1.743 mm) was significantly less than that of the approximated freehand group (2.638 mm, $P < .001$). Only in 11 of the 24 samples of the control group was surgical access considered clinically successful (within the apical area of the root), whereas all 24 of the experimental samples were considered clinically successful. **Conclusions:** Using a CBCT-designed printed surgical guide is a more accurate method for access to the apical portion of the root during surgical endodontics compared with a "freehand" CBCT-approximated method. (J Endod 2019;45:615–618)

Key Words

Apicoectomy, endodontic surgery, guided endodontics, printed guide, root-end surgery

Significance

Using a CBCT-designed 3D-printed surgical guide is a more accurate method for access to the apical portion of the root during surgical endodontics compared with a "freehand" CBCT-approximated method. These guides have the potential to increase accuracy and precision and to reduce intraoperative time as well as postoperative complications.

One major challenge during endodontic microsurgery involves locating the root end without damaging the surrounding structures (1). This is especially important in scenarios in which lesions have not yet perforated the cortical plate or in anatomically challenging locations that approximate vital structures (2). In addition, minimizing the size of the osteotomy has been correlated with favorable postoperative healing outcomes (3). Harnessing the power of technology has allowed practitioners to overcome some of these challenges. Using modern technology including magnification, illumination, microinstruments, and cone beam-computed tomographic (CBCT) scans has increased the precision involved in planning and performing endodontic surgery (4, 5). This study looked at optimizing the use of CBCT scans, specifically to not only visually plan surgery but also to fabricate surgical guides, similar to those that have been used in implant placement for more than a decade (6). These guides have the potential to increase accuracy and precision and to reduce the intraoperative time as well as postoperative complications (7–9).

Recent articles advocate for the use of 3-dimensional (3D)-printed guides to aid in nonsurgical endodontic access (10–12). A recent case report by Strbac et al (13) highlighted their potential use for surgical access. A series of case reports described using 3D-printed guides and trephine burs for anatomically challenging scenarios (14). Pinsky et al (15) compared the use of guided surgical access on alginate models of dry mandibles and found that the guides allowed for significantly more accurate osteotomy preparation than traditional methods. The purpose of this study was to explore the accuracy of the use of CBCT-designed 3D-printed surgical guides in surgical endodontic access compared with CBCT-approximated "freehand" access using a split-mouth design in a cadaver model. The hypothesis was that the use of CBCT-designed 3D-printed surgical guides allows the operator to more accurately access a root to a preplanned location compared with using CBCT imaging only to approximate surgical access.

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Targeted Endodontic Microsurgery: A Novel Approach to Anatomically Challenging Scenarios Using 3-dimensional–printed Guides and Trephine Burs—A Report of 3 Cases

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Abstract

Endodontic microsurgery (EMS) techniques have increased success rates over traditional approaches. Despite surgical advances, anatomically challenging scenarios can preclude EMS in certain cases. The aim of this article was to introduce targeted EMS, which uses 3-dimensional–printed surgical guides (3DSGs) and trephine burs to achieve single-step osteotomy, root-end resection, and biopsy in complex cases. In each of 3 cases, a 3DSG with a trephine port was printed using computer-aided design/computer-aided manufacturing implant planning software. The osteotomy site, angulation, and depth of preparation were defined preoperatively to avoid sensitive anatomic structures. The 3DSG was inserted at the target site to achieve precise osteotomy and root-end resection during surgery. A hollow trephine rotated within the 3DSG port produced single-step osteotomy, root-end resection, and biopsy. Root-end preparation and fill were accomplished, and tissues were sutured in place. Targeted EMS potentiated successful surgical treatment in 3 anatomically challenging scenarios: (1) a palatal approach to the palatal root of a maxillary second molar, (2) a facial approach to a fused distofacial-palatal root of a maxillary first molar, and (3) a mandibular second premolar in close proximity to the mental foramen. Trephine burs guided by 3DSGs produce efficient targeted osteotomies with a predictable site, angulation, and depth of preparation. Apical surgery in challenging anatomic cases such as the palatal root of the maxillary second molar, fused molar roots, and root ends in approximation to the mental nerve are possible with targeted EMS. *(J Endod 2018;44:671–677)*

Key Words

3-dimensional printing, apical surgery, endodontic microsurgery, palatal root, surgical guide, trephine stent

Advances in endodontic microsurgery (EMS) have steadily accumulated over the past 20 years resulting in its widespread use, greater efficiency, and improved outcomes (1). Nonsurgical root canal treatment and EMS provide viable options for dealing with irreversible pulpitis, pulp necrosis, and apical periodontitis in a majority of cases (2). EMS achieves desirable outcomes through enhanced visualization, magnification, and illumination; microsurgical instruments; ultrasonic root-end preparations; and the use of biocompatible materials (2). For EMS, a 35% increase in weighted, pooled success over antiquated techniques has been reported (1, 3).

Significance

Targeted EMS is useful for osteotomy and root-end resection when exacting control of depth, diameter, and angulation of osteotomy and root-end resection is necessary.

Cone-beam computed tomographic (CBCT) imaging provides increased visualization of canal morphology, periodontal ligament and bone aberration, root resorption, and appreciation of surrounding anatomic structures (4, 5). CBCT Digital Imaging and Communications in Medicine (DICOM) files converted into stereolithography files have been used in the production of 3-dimensional–printed surgical guides (3DSGs) for implant placement (6, 7). A limited number of articles document the applications of 3-dimensional (3D) printing in endodontics for use as presurgical planning models, endodontic access guides, surgical soft tissue retraction, and localization of the osteotomy perforation site (8–12). The precision and usefulness inherent in preoperatively designed 3DSGs has yet to be fully developed and implemented in EMS.

Trephine burs have been used for the removal of failed implants and autogenous bone graft harvesting but have not previously been described in EMS (13–15). The second and third authors developed a technique (targeted EMS) that combines CBCT and computer-aided design/computer-aided manufacturing to generate 3DSGs for use with trephines. Targeted EMS produces a single-step osteotomy; root-end resection; and biopsy with a defined perforation site, angulation, depth, and diameter. Previous reports have used 3DSGs to locate an ideal bone perforation site, but none have used trephine burs within a stent to define all parameters of osteotomy and root-end resection (12, 16).

Targeted EMS Technique Overview

An 80 × 80 mm preoperative CBCT scan was required (3-D Accuitomo 170; J Morita USA, Inc, Irvine, CA) and a polyvinyl siloxane (PVS) impression (Aquasil Ultra; Dentsply Caulk, Milford, DE) was made and poured. To overcome restoration-

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