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The effectiveness of the SWEEPS modality in an Er:YAG laser to treat complex anatomy in three challenging clinical cases

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ABSTRACT

The goal of endodontic therapy is to eliminate pathogenic substances from the root canal system. Endodontic treatment often presents the clinician with several challenges, including the complex morphology of the root canal system, the dentinal walls and tubules are heavily infected, and in cases of immature teeth, the canals are very wide and the remaining dentin root walls are thin and prone to root fracture. Mechanical over-shaping and widening of the root canals is contraindicated in certain clinical cases, therefore we must rely on irrigation methods to provide sufficient disinfection of the root canal system. Since root formation often ceases due to pulp necrosis in immature teeth, there is also no physiological apical constriction, and the apical foramen is often very patent.

This presents the clinician with the challenge of preventing extrusion of the irrigants as well as the filling material during endodontic treatment.

Different disinfection methods and technologies have been introduced with the goal to improve the efficacy of the standard syringe root canal irrigation procedure. One of the most recent techniques involves SSP/SWEEPS® laser- assisted irrigation (LAI) using an Er:YAG (erbium-doped yttrium aluminum garnet) laser with extremely short laser pulses, generating photon-induced photoacoustic streaming of the irrigant throughout the complex root canal system.

Three cases are presented including treatment of acute apical periodontitis in an immature maxillary central incisor with a very patent apical foramen, treatment of an irreversible pulpitis in a maxillary second molar tooth with extreme canal curvature and treatment of a mandibular molar tooth with chronic apical periodontitis and periodontal involvement using the SWEEPS LAI protocol. Results showed successful treatment outcomes with 1-year follow-ups. The SWEEPS LAI technique may represent a paradigm shift in the way we perform minimally invasive endodontic treatments, by decreasing the amount of mechanical instrumentation, thus avoiding possible treatment complications associated with difficult root canal anatomies and improving disinfection.

Keywords: Er:YAG, SSP, SWEEPS, laser-assisted irrigation, laser endodontics, photon-induced photoacoustic streaming, shockwave enhanced emission photoacoustic streaming, root canal treatment, endodontic treatment, minimally invasive endodontics, acute apical periodontitis, complicated root canal morphology, endo-perio lesion

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I. INTRODUCTION

The main goal of endodontic treatment is the removal of inflamed pulp tissue aseptically or the removal of all necrotic pulp tissue as well as the elimination or reduction of the bacterial count and bacterial toxins to biologically acceptable levels, which allow for the healing of periodontal tissues. This is achieved by mechanical instrumentation and enlargement of the main canals coupled with the use of chemical irrigants, mainly NaOCl and EDTA. Endodontic treatment is completed with obturation of the cleaned canal system followed by a coronal restoration. Due to the complexity of the root canal system, this is often very difficult to achieve.

The root canal morphology is very variable and can range from simple cases with a single canal to extremely complicated cases with several canals and different intra-canal communications as well as lateral canals. Histological and micro-CT studies have shown that the root canal morphology is usually the most complicated in the apical part of roots, where we find apical ramifications in 75% of teeth (Ricucci and Siqueira, 2010). Teeth that have more than one canal in a single root will usually have different kinds of communications between these canals. According to the results of several studies, isthmuses can be found in 62-86% of mesio-buccal roots of upper molars (von Arx, 2005), 60-89% of mesial roots of lower molars (Vertucci, 1984) and 19-65% of upper premolars (Weng et al., 2009). Mechanical instrumentation has shown several limitations when it comes to the disinfection of the root canal system. Paqué and his research team has shown that during mechanical instrumentation a large portion (ranging from 40-50%) of the canal walls remains untouched (Paqué et al., 2009). Also, during instrumentation, debris as well as bacteria might get pushed into these canal irregularities, thus causing a persistent infection and incomplete healing of the periapical tissues. The main aim of mechanical instrumentation is in providing a shape to the canals, which will promote successful penetration of the irrigation solutions to all parts of the root canal system.

Another challenge in endodontics is the treatment of immature teeth. Several etiological factors can lead to arrested tooth development, the main being dento-alveolar trauma (35%), progressed caries lesions (15%) and morphological variations in tooth development such as dens invaginatus and dens evaginatus.

Endodontic treatment of such teeth often presents the clinician with several challenges, including that the remaining dentin root walls are thin and prone to root fracture. Mechanical shaping and widening of the root canals are thus contraindicated and we must rely on different irrigation methods to provide sufficient disinfection of the root canal system. Since root formation often ceases due to pulp necrosis, there is also no physiological apical constriction, and the apical foramen is very patent. This presents the clinician with another challenge of preventing extrusion of the irrigants and root filling material.

Several treatment options are available ranging from long-term apexification using calcium hydroxide, short-term apexification using biocompatible materials such as MTA or Biodentine or regenerative endodontic procedures (REP).

Since the treatment outcome is highly dependent on our ability to completely disinfect the root canal system and since shaping of the canals is not advised, new irrigation methods that can enhance the disinfection efficacy of the root canal system are needed.

Teeth with endo-perio lesions have inflammatory lesions that, due to the anatomical connections of the root canal system with the periodontium through dentinal tubules, lateral and accessory canals and the apical foramen, affects both structures.

Since patients often present with advanced lesions that are often in an acute stage of inflammation, it is often difficult to discern whether these lesions are two separate entities or are combined, as well as which is the primary lesion and which is the secondary lesion. Endo-perio lesions may also resemble other pathological conditions, such as vertical root fractures. Clinically, we often see a tooth that is tender to percussion and palpation, with increased mobility, swollen gingival tissue, and sometimes an open sinus tract in the vestibulum as well as a deep periodontal pocket. There may be an acute abscess and pus draining from the sinus tract and pocket. For the correct diagnosis, it is imperative that we take a detailed dental history regarding the tooth as well as do a careful clinical examination and analysis of both intraoral radiographs and CBCT scans before starting with the treatment. To help differentiate the aetiology of the endo-perio lesion, the lesions origin needs to be determined.

In teeth with a primary endodontic and secondary periodontal involvement, the tooth is usually non-vital, has a deep caries lesion or deep filling, has had a history of dental trauma and has a localized deep periodontal pocket, while in lesions that have a primary periodontal with secondary endodontic involvement, the tooth is usually vital, very sensitive to thermal stimulus, with no caries or restorations and has broad periodontal attachment defects.

Primary endodontic lesions with secondary periodontal involvement should first be treated endodontically, followed by a waiting period of 2-3 months for the periodontal status to resolve, and finished with periodontal treatment if needed. Regarding the endodontic treatment, it is imperative that the disinfection of the root canal system be as effective as possible since the canal system has an established infection and the bacteria have probably penetrated deeply into the dentinal tubules. Modern endodontics acknowledges that irrigation and chemical disinfection play the most important role for the success of endodontic treatment. Studies have shown that when we rely only on conventional needle irrigation, limitations regarding the velocity and the flow of the irrigant can be observed in the root canals (Boutsioukis et al., 2010, Boutsioukis and Gutierrez Nova, 2021).

The flow of the irrigant is usually limited to only a few mm from the tip of the needle, depending on the pressure applied, the tip design and also the apical preparation size and taper of the shaped canal (Boutsioukis et al., 2010). Studies have shown that larger tapers of 0.4 - 0.6 and ISO apical size of at least 35-40 are needed to enable satisfactory irrigation in the apical part of the root, if only conventional needle irrigation is used (Albrecht et al., 2004). An alternative approach is to use agitation techniques, which enhance the streaming of the irrigants and enable better cleaning of necrotic tissue, smear layer and debris removal, as well as removal of bacterial biofilm from all parts of the root canal system.

One of the most recent techniques involves SSP/SWEEPS® laser-assisted irrigation (LAI) using a type of the Er:YAG (erbium-doped yttrium aluminum garnet) laser with extremely short laser pulses, generating photon-induced photoacoustic streaming of the irrigant throughout the complex three- dimensional root canal system (Ivanusic et al., 2019). High forces and shear stress created along the dentinal walls are strong enough to remove dentin debris and biofilm. In vitro studies have shown SSP/SWEEPS LAI to be superior to passive ultrasonic irrigation (PUI) when it comes to the removal of debris (Lloyd et al., 2014), microorganisms (Cheng et al., 2012; Olivi et al., 2014), calcium hydroxide medication (Arslan et al., 2015) or old filling materials (Jiang et al., 2016). SSP/SWEEPS endodontics has also been shown to be more effective compared to other irrigation methods (PUI, conventional needle irrigation, sonic activation, mechanical agitation) when it comes to agitation of the sodium hypochlorite and complete disinfection of the root canals (Olivi et al., 2014; Balić et al., 2016; De Meyer et al., 2017) as well as deeper parts of the dentinal tubules (Al Shahrani et al., 2014; Azim et al. 2016). Due to the increased disinfection efficacy, the SSP/SWEEPS endodontics protocols have significant benefits in enhancing the effectiveness of irrigation during endodontic treatment, especially in teeth with complicated root canal morphology.

When comparing both LAI methods, SWEEPS has been shown to generate higher amplification in liquid pressure inside a closed space when compared to the SSP mode. This is due to the fact that the second pulse in an optimal time delay greatly accelerates the collapse of the primary bubble, thus amplifying the generated shock waves and shear stresses of the irrigant along the dentinal walls (Lukač et al, 2017). Based on the preliminary and in vitro studies, our aim was to test the SWEEPS LAI technique as a method of choice for clinical cases of acute apical periodontitis, irreversible pulpitis with extreme root canal curvature and chronic apical periodontitis with periodontal involvement (endo-periolesion).

II. CASES

a) Case I: Acute apical periodontitis of tooth 11, immature root with unformed apex

A 27-year-old male patient presented to our clinic presenting with pain, an acute abscess, an open sinus tract and pus secreting in the vestibular region

of his upper central right incisor (tooth 11). The patient was healthy, stating only slightly elevated blood pressure, but was not taking any medication. He had no allergies. The patient had had an accident early in his childhood when he fell on his face and fractured his central incisors. At that time the edges of both central incisors had fractured and then been rebuilt using composite material. No endodontic treatment was performed. The intraoral clinical examination showed that tooth 11 had a composite build-up on the mesial surface and at the incisal edge. Tooth 11 was necrotic and did not react to the vitality tests (ethyl-chloride cold test (Euronda, Monoart) and an electrical pulp test (Dental Electronic)). It was very tender to percussion as well as highly sensitive to palpation adjacent to the apex of the tooth. There was an open sinus tract in the vestibule with secreting pus (Figure 1). The mobility of the tooth had not increased. Probing depth was normal. A periapical radiograph showed that tooth 11 had an immature root that was partially resorbed with an unformed apex. The beginning of bone resorption could be seen near the apex indicating acute apical periodontitis (Figure 2).

Figure 1: Acute apical periodontitis of tooth 11. First examination revealed an open sinus tract in the vestibule with secreting pus.

Figure 2: Pre-operative periapical radiograph of tooth 11 and 12 showing immature root of tooth 11 that was partially resorbed with an unformed apex. The beginning of bone resorption could be seen near the apex indicating acute apical periodontitis.

At the first clinical appointment, the region of both central incisors was anesthetized by local infiltration using articaine hydrochloride with 1:100.000 epinephrine (Ubistesin, 3M ESPE). Due to the fact that both teeth were non- vital, the endodontic treatment was performed on both upper central incisors. First a rubber dam was placed on tooth 11 and the working field was isolated with rubber dam isolation material. An endodontic access cavity was prepared and a larger file (# 0.50) was used to check for the patency of the canal. The size of the apical foramen was measured at ISO 120 (# 1.20).

Due to the presence of significant amounts of necrotic tissue in the canal as well as ingrowing granulation tissue from the periapical region, it was decided to use the SWEEPS irrigation protocol at the beginning of endodontic treatment. It has been shown that laser-activated irrigation can greatly increase the dissolution of organic material by agitating sodium hypochlorite, thus greatly increasing the cleaning of the root canal (De Meyer et al., 2017). Since the size of the apical foramen was ISO 120 and the canal was very patent, no mechanical shaping was done. The LightWalker ST-E Er:YAG laser system was used with the HC14-N handpiece with a Flat SWEEPS400/14 fiber tip, energy of 20 mJ, AutoSWEEPS mode, frequency 15 Hz, power 0.30 W, irrigation time 30 seconds followed by 30-second rest phase, no water, no air, irrigant (2.5% sodium hypochlorite (CanalPro, Coltene)) in the access cavity. When no more necrotic tissue or remnants of granulation tissue could be seen coming out of the canal, the final irrigation protocol was performed. This irrigation protocol consisted of a 30-second irrigation cycle with 17 % EDTA (CanalPro, Coltene), followed by one cycle of distilled water and three 30-second cycles of 2.5% sodium hypochlorite. After drying, calcium hydroxide dressing (UltraCal XS, Ultradent) was put in the canal and the endodontic access cavity was temporarily sealed using Cavit G (3M ESPE). The same clinical procedure was repeated on the left upper incisor.

At the second clinical appointment, the calcium hydroxide was removed and one 30-second EDTA cycle followed by one 30-second distilled water cycle and three cycles of 30-second SWEEPS irrigation with 2.5% sodium hypochlorite was performed at the same energy setting as at the first clinical appointment.

After rinsing with distilled water and drying the canal with paper points, a biodegradable material (Hemocollagene, Septodont) was placed periapically to provide a barrier against which biocompatible cement (ProRoot MTA, Dentsply, Maillefer) was tightly packed in a 3 mm increment and left to dry. After that a fiber-reinforced post (FRC Postec, Ivoclar, Vivadent) was adhesively bonded using adhesive cement (Multilink, Ivoclar, Vivadent) and a final composite restoration using Tetric EvoCeram (Ivoclar, Vivadent) was placed in the access cavity. Follow-up appointments were performed after 2 weeks and after one year.

During and after all clinical procedures, the patient did not experience any discomfort. Post-operatively, there were not any clinical symptoms that would indicate the extrusion of sodium hypochlorite. At the second appointment, the sinus tract in the vestibule had completely closed and the gingival tissue had a healthy appearance (Figure 3). A 1-year follow-up showed complete healing of the periapical lesion with complete regeneration of the bone (Figure 4).

Figure 3: At the second appointment at 14-days post-op, the sinus tract in the vestibule at tooth 11 had completely closed and the gum had a healthy appearance.

Figure 4: A 1-year follow-up periapical radiograph showed complete healing of the periapical lesion with complete regeneration of the bone.

b) Case II: Irreversible pulpitis with extreme root canal curvature

A 56-year-old male patient was referred to our clinic due to a deep caries lesion, irreversible pulpitis and acute pain. Due to the complex root canal anatomy of the extreme curvature of the mesio-buccal root, the referring dentist decided that this clinical case should be done by an endodontist. The patient was healthy and taking no medication, stating only glaucoma treated in the past. He had no allergies. The dental history of the patient did not reveal any trauma to the teeth. The patient had practiced good oral hygiene. The intraoral clinical examination showed that tooth 27 had a temporary filling on the mesial side of Cavit. The tooth was very tender to percussion but only slightly sensitive to palpation adjacent to the apex of the tooth. The tooth reacted to both vitality tests, an ethyl-chloride cold test (Euronda, Monoart) and an electrical pulp test (Dental Electronic), and the patient felt a sharp pain of high intensity, which lasted for some minutes before subsiding. The mobility of the tooth was not increased. Probing depth was normal except for the distal surface of the tooth, where the probing depth was 4 mm. A radiograph showed a large mesio-occlusal restoration extending to the pulp chamber. Three roots could be observed, the palatal root was straight, and the disto-buccal root was slightly curved distally, while the mesio-buccal root showed a high degree of double curvature with the angle of curvature reaching almost 90 degrees on the first curvature and slightly less on the second curvature (Figure 5). The periodontal ligament was normal in width. The periapical bone didn't show any signs of resorption.

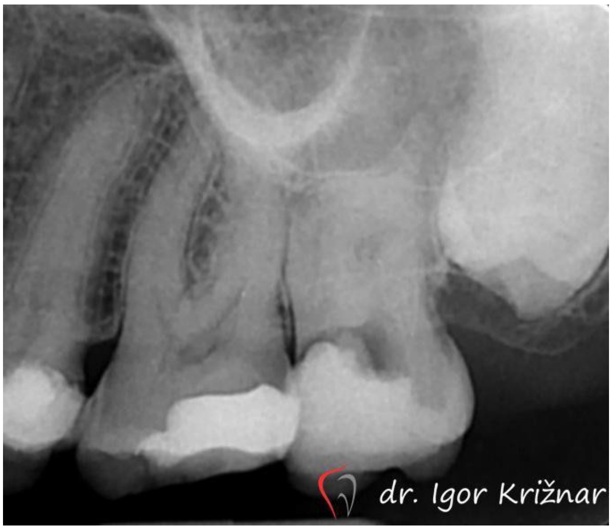

Figure 5: Irreversible pulpitis of tooth 27. A pre-operative radiograph showed a big mesio- occlusal filling reaching all the way to the pulp chamber. Three roots could be observed, the palatal root was straight, the disto-buccal root was slightly curved distally, while the mesio-buccal root showed a high degree of double curvature with the angle of curvature reaching almost 90 degrees on the first curvature and slightly less on the second curvature.

In this clinical case a decision was made to use the SWEEPS irrigation protocol. When treating teeth with extreme root canal curvatures above 35 degrees, shaping of the root canals to larger files and tapers brings additional risks of clinical errors such as root perforation, instrument breakage, ledge formation and apical transportations. A more prudent alternative is to be as conservative as possible with the shaping, but to increase the effectiveness of irrigation by using the SWEEPS or SSP LAI protocol.

In the first session an anesthetic articaine hydrochloride with epinephrine (1:100,000) (Ubistesin, 3M ESPE) was administered by local infiltration using a 30-gauge needle in the vestibular and palatal region near the apex of tooth 27. A rubber dam was placed on the tooth and the working field isolated with rubber dam isolation material. An endodontic access cavity was prepared and the root canal was negotiated to the apex with a # 0.06 hand C-file. For the shaping of the root canal system, the Coltene Hyflex CM and EDM systems with controlled memory files were used. Coronal flaring of the canal was done with the Hyflex EDM orifice opener and then scouting with hand files apical size 06. The glide path was prepared with the use of hand instruments and the Pathfinder NiTi instrument. From then on, the shaping of the canal was done using both the Hyflex EDM and CM instruments, but it is important to note that the preparation of the mesio-buccal canals was performed only to a size 20/04. The DB and P canals were prepared to size 30/04. Between each file, SWEEPS irrigation protocol with 6% sodium hypochlorite (CanalPro, Coltene) in the access cavity for 30 seconds was applied. The LightWalker ST-E Er:YAG laser system was used with HC14- N handpiece, conical sapphire600/12 fiber tip, AutoSWEEPS mode, energy 20 mJ, frequency 15 Hz, power 0.30 W, irrigation time 30 seconds, followed by 30- second rest phase, no water, no air, irrigant in the access cavity (Figure 6). A final irrigation protocol consisted of a 30-second irrigation cycle with EDTA, followed by one cycle of distilled water and three 30-second cycles of 6% sodium hypochlorite. After drying the canals, a calcium hydroxide dressing (UltraCal XS, Ultradent) was put in the canals and the endodontic access cavity was temporarily sealed using Cavit G (3M ESPE).

Figure 6: Tooth 27 after mechanical shaping of the canals with the endodontic access cavity prepared, filled with 6% sodium hypochlorite and ready for the SWEEPS irrigation protocol.

At the second appointment after 2 weeks, the calcium hydroxide dressing was removed and one 30-second EDTA cycle followed by rinsing the canal with distilled water and three cycles of 30-second SWEEPS irrigation with sodium 6% sodium hypochlorite were repeated. The canals were dried and filled using gutta percha points (VDW) and AH Plus sealer and the warm vertical compaction technique. A temporary filling made of a glass ionomer cement (Fuji IX, GC) was placed and a periapical radiograph taken (Figure 7). The patient was scheduled for a follow-up appointment after 10 months.

Figure 7: Post-op periapical radiograph of tooth 27 at 2-week follow-up after final root canal filling of the canals.

During and after the clinical procedure the patient felt no pain or discomfort. A review periapical radiograph taken at the 1-year follow-up (Figure 8) revealed a successful endodontic treatment of a tooth with extreme root canal curvature using the SWEEPS irrigation protocol for the disinfection of the root canal system before the final root canal filling.

Figure 8: Periapical radiograph at 1-year follow-up showing successful endodontic treatment of tooth 27 with extreme root canal curvature using the SWEEPS irrigation protocol for cleaning and disinfection of the root canal system.

c) Case III: Chronic apical periodontitis with periodontal involvement of tooth 46 (endo-perio lesion)

A 30-year-old female patient was referred to our clinic for endodontic treatment of a lower molar due to an acute abscess, an open sinus tract and increased probing depth reaching all the way to the apex of the mesial root. She stated that a few weeks earlier she started feeling tenderness under the first molar, which slowly progressed until moderate pain, slight swelling and an open sinus tract with pus secreting had developed. She visited her dentist who referred her to our clinic. The patient was healthy and taking no medication, she stated that she was lactose intolerant. The dental history of the patient did not reveal any trauma to the dentition. The patient had excellent oral hygiene. The intraoral clinical examination showed that tooth 46 had a large buccal-occlusal-lingual-distal composite filling with secondary caries. The tooth was moderately tender to percussion as well as sensitive to palpation. There was an open sinus tract secreting pus as well as an increased probing depth with the periodontal probe reaching down to the apex of the root along the buccal surface of the mesial root (Figure 9). The mobility of the tooth was not increased. There was also a slight swelling in the submandibular region of the jaw, which was tender to palpation. A radiograph taken showed a large occlusal distal filling. The tooth had not been endodontically treated in the past. There was a large bone lesion periapically under the mesial root that extended along the whole length of the root all the way into the furcation area (Figure 10).

Figure 9: Tooth 46 showing open sinus tract and increased probing depth.

Figure 10: Pre-operative periapical radiograph of tooth 46 before endodontic treatment. There was a large bone lesion periapically under the mesial root that extended along the whole length of the mesial root all the way into the furcation area.

For the endodontic treatment the distal aspect of tooth 46 was first rebuilt using composite material Tetric EvoCeram (Ivoclar, Vivadent).

The lower right jaw was anesthetized by mandibular infiltration using articaine hydrochloride with 1:100,000 epinephrine (Ubistesin, 3M ESPE). A rubber dam was placed on the tooth and the working field was isolated with rubber dam isolation material. An endodontic access cavity was prepared and the root canals were negotiated to the apex with a # 0.08 hand C-file. Since the root canal system had a relatively simple morphology, a decision was made to shape the canals to working length to size # 0.35 for the mesial canals and # 0.45 for the distal canal using Hyflex CM and EDM instruments (Coltene, Germany) in a sequential technique. The pulp chamber was heavily infected therefore copious amounts of 6% sodium hypochlorite were used during the shaping procedure in combination with the AutoSWEEPS mode using the LightWalker ST-E Er:YAG laser system, HC14- N handpiece with Flat SWEEPS400/9 fibertip, pulse energy of 20 mJ, frequency 15 Hz, power 0.30 W, irrigation time 30 seconds followed by 30-second rest phase, no water, no air, irrigant in the access cavity. In cases, where the periapical pathology has evolved, and we suspect that the root canal system has been exposed to an infection for a longer time, it is advisable to raise the concentration of sodium hypochlorite to higher concentrations as well as increase the number of the irrigation cycles with SWEEPS mode to get a maximal disinfection effect (Haapasalo et al., 2014, Wang et al., 2012). In this clinical case the final irrigation protocol was one 30-second irrigation cycle with EDTA to open up the dentinal tubules, followed by one cycle of distilled water and six 30-second cycles of 6% sodium hypochlorite. The irrigation with SWEEPS and sodium hypochlorite was carried out until no more debris or necrotic pulpal remnants could be seen coming up from the root canals and the irrigation solution in the endodontic access cavity was totally transparent. After drying, calcium hydroxide dressing (UltraCal XS, Ultradent) was put in the canals and the endodontic access cavity was temporarily sealed using a glass ionomer cement (Fuji IX, GC).

In cases where there is a deep periodontal pocket present, the medication should be left for a longer period, usually 1-2 months, to see some kind of gingival reattachment taking place before commencing with the final root canal filling. At the second appointment after a month and a half, the periodontal pocket had completely healed and the probing depth was reduced to physiological levels (Figure 11). The patient had no clinical symptoms therefore the calcium hydroxide was removed, the intensified SWEEPS irrigation protocol from the first session was repeated and finally the canals were dried and filled using gutta percha points (VDW), AH Plus sealer (Dentsply, Maillefer) and the warm vertical compaction technique. A temporary filling (Fuji IX, GC) was placed and an X-ray was performed (Figure 12). The patient was scheduled for a follow- up appointment after 10 months.

Figure 11: Closing of the sinus tract and healing of deep periodontal pocket of tooth 46 at 1.5-month follow-up.

Figure 12: Post-operative periapical radiograph of tooth 46 after temporary root canal filling at 1.5-month follow-up.

During and after the clinical procedure, the patient felt no pain or discomfort and the acute symptoms subsided very quickly. A 1-year radiographic follow- up showed great healing of the periapical bone lesion as well as the healing of the bone lesion in the furcation area (Figure 13). There was complete regeneration of the periodontal tissues. Our clinical case presents the advantage of using the SWEEPS irrigation protocol for complete disinfection of heavily infected root canal systems.

Figure 13: Periapical radiograph of tooth 46 at the 10-month follow-up showing great healing of the periapical bone lesion as well as healing of the bone lesion in the furcation area.

III. DISCUSSION AND CONCLUSIONS

These case reports show the successful use of the SWEEPS LAI cleaning protocol for endodontic indications such as acute apical periodontitis in immature teeth, irreversible pulpitis with extreme root canal curvature and chronic apical periodontitis with periodontal involvement (endo-perio lesion). This method can be used at the beginning of endodontic treatment; since it has been shown that laser-activated irrigation can greatly increases the dissolution of organic material by agitating sodium hypochlorite, thus greatly increasing the removal of vital and non-vital pulp tissue, as well as granulation tissue, resulting in greater cleanliness of the root canal system. Due to the enhanced agitation and activation of sodium hypochlorite in a confined system, better disinfection can be expected. If needed and if the safety parameters are met, it is possible or advised to use higher concentrations of sodium hypochlorite as well as more irrigation cycles to further improve the disinfection of the complex root canal systems in order to achieve even more predictable healing of periapical and endo-periodontal lesions.

The disinfection efficacy of the SWEEPS LAI cleaning protocol has been proven to be very effective and completely safe, also when it comes to endodontic treatment of teeth with immature roots and open apical foramina. A concern that we face when agitating the irrigant solution during endodontic treatment is the extrusion of sodium hypochlorite into the periapical tissues, which can cause tissue necrosis and damage to the cancellous bone, resulting in severe pain, emphysema and facial swelling. Thus, it is important to minimize the extrusion of irrigants. When the parameters of laser light are used in accordance with the manufacturer's recommendations, or are slightly adjusted, there is minimal risk of irrigant extrusion even in teeth with wide-open apexes. With the SWEEPS cleaning technique, we can make a paradigm shift in endodontic treatments. Since this technique greatly increases fluid dynamics and therefore the cleaning rate (Lukač et al., 2017, Ivanušič et al., 2019), with the result that sodium hypochlorite reaches even the most apical parts of the root canal system and provides sufficient disinfection, we don't need to prepare canals to larger apical sizes or tapers, which is the case when only conventional irrigation methods are used. Moreover, this technique is crucial when it comes to many endodontic treatments, especially of teeth with complicated root canal morphologies. When treating teeth with extreme root canal curvatures, shaping of the root canals to larger files and tapers brings additional risk of clinical errors such as root perforation, instrument breakage, ledge formation and apical transportations. A wiser alternative is to be as conservative as possible with the shaping, but on the other hand increase disinfection efficacy by using the SWEEPS cleaning protocol, thus embracing the principles of minimally invasive endodontics.

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