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Case Report

Revascularization of an Immature Permanent Tooth with Periapical Periodontitis Using Concentrated Growth Factor Assisted by Erbium Laser (2940 nm) Irrigation: A Case Report

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Featured Application: Er: YAG irrigation is an efficient root canal disinfection protocol with the advantages of easy operation and minimal risk, which might be applicable to revascularization of necrotic immature permanent teeth.

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Abstract: Revascularization has been incorporated into endodontic practice and become a viable treatment alternative for immature teeth with pulp necrosis. Thorough disinfection of the root canal is a key factor for successful revascularization. An erbium: yttrium–aluminium–garnet (Er: YAG) laser has been proved advantageous for efficient root canal disinfection. This article reports one case of periapical periodontitis caused by a fractured occlusal tubercle. Revascularization assisted by Er: YAG laser irrigation was carried out with long-term follow up. During the process of treatment, we opened drainage to relieve the acute symptoms first. The necrotic pulp was removed, and then the root canal was rinsed with 0.5% sodium hypochlorite (NaOCl) solution assisted by Er: YAG laser irrigation, dried, and filled with a triple-antibiotic paste. After two weeks, the intracanal medication was removed, and 9 mL of whole vein blood was taken from the patient to prepare concentrated growth factor (CGF) after failing to induce enough blood into the canal system by over-instrumenting. The newly prepared CGF was transferred into the root canal. A 3 mm mineral trioxide aggregate (MTA) was placed directly on the thrombus of the CGF and then restored with glass-ionomer cement (GIC). The case was followed up for more than four years to record the clinical symptoms and imaging manifestations. Er: YAG irrigation is an efficient root canal disinfection protocol with the advantages of easy operation and minimal risk, which might be applicable to the revascularization of necrotic immature permanent teeth.

Keywords: erbium laser; irrigation; immature permanent teeth; periapical periodontitis; concentrated growth factor; regenerative endodontics

1. Introduction

Periapical periodontitis of immature permanent teeth is commonly caused by caries, trauma, or dens evaginatus. The cleaning, shaping, and obturating of the root canal system are challenging when treating infected pulp in immature permanent teeth [1]. Meanwhile, nonvital immature teeth have fragile dentinal walls, which are susceptible to fracture resulting in tooth extraction [2]. The traditional treatment for immature necrotic teeth is apexification [3]. However, the process requires several visits and a long treatment course. Additionally, the dressing may be absorbed gradually into the root canal. Recently, more attention has been paid to apical barrier technology, but it has high technical sensitivity and involves a complex operation process. Currently, there are increasing cases of revascularization due to its the advantages, including a simple operation and a better clinical effect on the thickening of canal walls and closure of the apex [4,5]. The principle of revascularization is to provide a sterile root canal that allows new cells to populate, that is, to rebuild pulp vitality [6]. The induction of bleeding and formation of an intracanal blood clot is a current procedure used in revascularization to provide a scaffold for pulp–dentin regeneration. When adequate bleeding cannot be achieved, concentrated growth factor (CGF) may be a suitable alternative scaffold in revascularization [2].

Irrigation is an essential part of the chemo-mechanical preparation of root canals in revascularization [7]. Compared with passive ultrasonic irrigation and hand irrigation, Erbium: yttrium–aluminium–garnet (Er: YAG) laser-activated irrigation was significantly more effective in removing dentine debris from the apical part of the root canal. It works via laser pulses vaporizing the irrigant. The resulting bubbles collapse, creating shockwaves, and generating cavitation effects [8]. A number of in vitro studies have proved the advantage of efficient root canal disinfection with an Er: YAG laser [7,9–11]. However, to the best of our knowledge, there is no case report on the use of laser-assisted irrigation in revascularization. This report presents the clinical and imaging effects of the revascularization of an immature permanent tooth with periapical periodontitis assisted by Er: YAG laser irrigation.

2. Case Report

2.1. Clinical History

An 11-year-old girl complained of pain in the left mandibular posterior tooth, which manifested as persistent pain aggravated by occlusion. One day prior, the left side of the patient's face was swollen.

2.2. Clinical Exams and Diagnosis

As shown in Figure 1, clinical examination showed a fractured occlusal tubercle in the left mandibular second premolar accompanied by gingival swelling. Tooth mobility was categorized as class I (Miller's index) [12]. The pulp sensibility tests, including cold testing and electric pulp testing, were both negative. The periapical radiograph revealed incomplete root formation with an open apex and periapical radiolucency (Figure 1). After consultation, the child was found to have no history of allergies. Based on the acute clinical symptoms and periapical radiolucency, a diagnosis of acute exacerbation of chronic periapical periodontitis in tooth 35 was made.

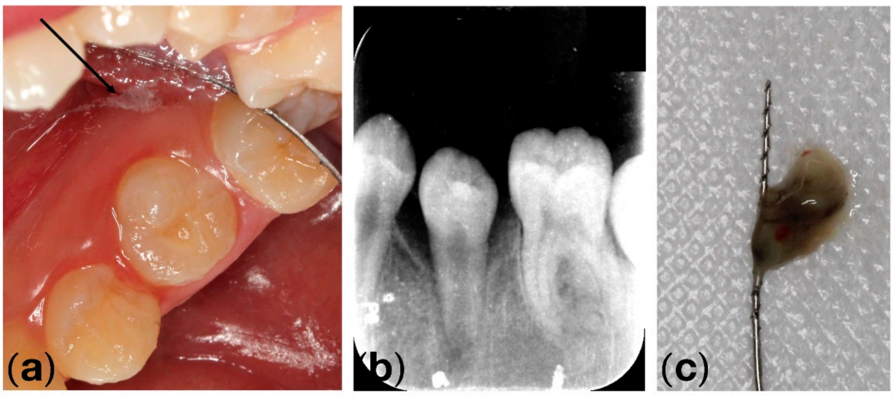

Figure 1. The first visit. (**a**) A fractured occlusal tubercle in the left mandibular second premolar accompanied by gingival swelling; (**b**) Periapical radiolucency of tooth 35; (**c**) Purulent secretion.

2.3. Therapeutic Plan

The treatment plan was to perform revascularization of tooth 35. After a detailed explanation of the treatment plan, written informed consent was obtained from the patient's parents.

Under rubber dam isolation, the cavity was accessed with a high-speed air turbine. Purulent secretion was found in the chamber (Figure 1). The cavity was kept open for two days with a small cotton roll to establish drainage and relieve the acute symptoms. At the next appointment, under a rubber dam, the root canal was chemically debrided without mechanical instrumentation using 20 mL 0.5% sodium hypochlorite (NaOCl) assisted by Er: YAG laser irrigation with the photon-induced photoacoustic streaming (PIPS) procedure, that is, low energy (20 mJ), a low pulse repetition rate (15 Hz), and a very short pulse length (50 us) with a radial stripped novel fibre tip (Figure 2). The fibre tip was inserted in the pulp chamber (about 7 mm depth from the coronal reference) and kept in a stable position without advancement into the canal orifice (Figure 2). The procedure was four cycles of 20-s activation by PIPS followed by four rounds of 5-s off cycles. At the end of the irrigation phase, the canal was dried with paper points. A resin bond was applied without etching onto the access cavity walls and the coronal third of the root canal. A triple-antibiotic paste (1:1:1 ciprofloxacin: metronidazole: minocycline) was placed into the middle and apical thirds of the root canal, and the access was restored with Cavit™.

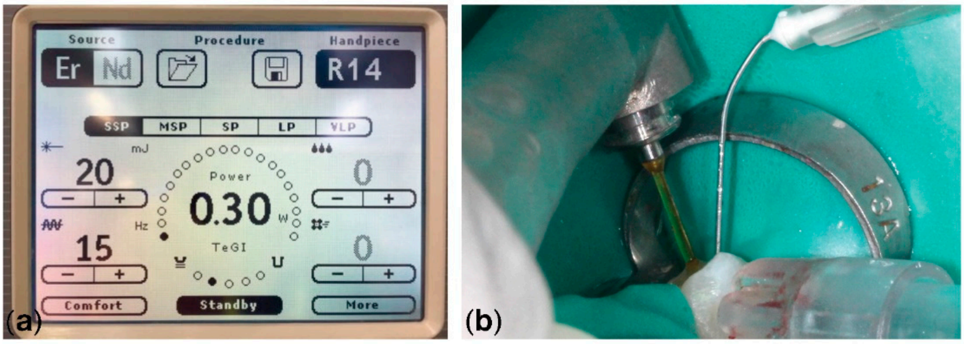

Figure 2. Irrigation assisted by Er: YAG laser. (**a**) PIPS procedure; (**b**) Chemically debriding using 0.5% sodium hypochlorite assisted by Er: YAG laser with the PIPS procedure.

Two weeks later, the tooth was asymptomatic and not tender to percussion and palpation. Under rubber dam isolation, the access cavity was reaccessed, and the triple-antibiotic paste was flushed out of the canal using 30 mL 0.5% NaOCl assisted by Er: YAG laser irrigation with the PIPS procedure. The canal was dried with paper points.

After failing to induce enough blood into the canal system by over-instrumenting, a 9 mL sample of whole venous blood was drawn from the patient's forearm (right median cubital vein). The blood sample was collected into a test tube without anticoagulant and centrifuged immediately using a tabletop centrifuge by 30 s acceleration, 2 min at 2700 rpm (600 g), 4 min at 2400 rpm (400 g), 4 min at 2700 rpm (600 g), 3 min at 3000 rpm, and 36 s deceleration. Three distinct layers were formed in the tube: platelet poor plasma at the top, CGF in the middle, and red blood cells at the bottom (Figure 3). After centrifugation, sterile tweezers were inserted into the tube to gently grab and keep the CGF extracts. The CGF extracts close to the red blood cell layer were squeezed between the sterile dry gauge to drive out the fluids trapped in the fibrin matrix and thereby obtain an autologous fibrin membrane. The freshly prepared CGF membrane was fragmented, and the fragments were placed incrementally in the canal using a finger plugger up to the level of the cement–enamel junction (CEJ) (Figure 4). A 3-mm-thick layer of white mineral trioxide aggregate (MTA) was placed directly over the CGF matrix. The tooth was restored using glass-ionomer cement (GIC).

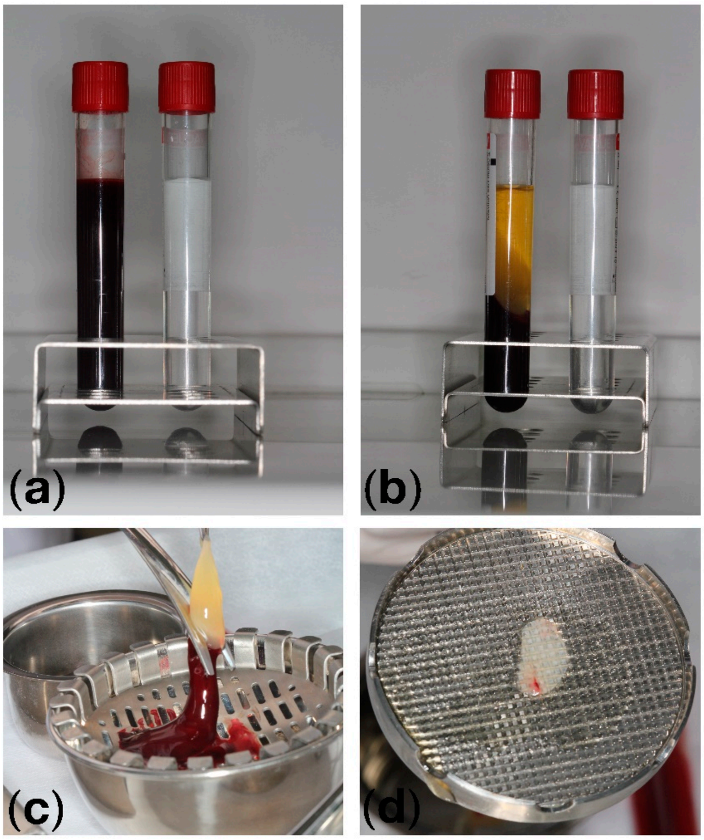

Figure 3. The process of preparing a CGF membrane. (**a**) Nine millilitre sample of whole venous blood; (**b**) CGF extracts close to the red blood cell layer after centrifugation; (**c**) the retained CGF extracts; (**d**) the fibrin membrane obtained from squeezing the CGF extracts.

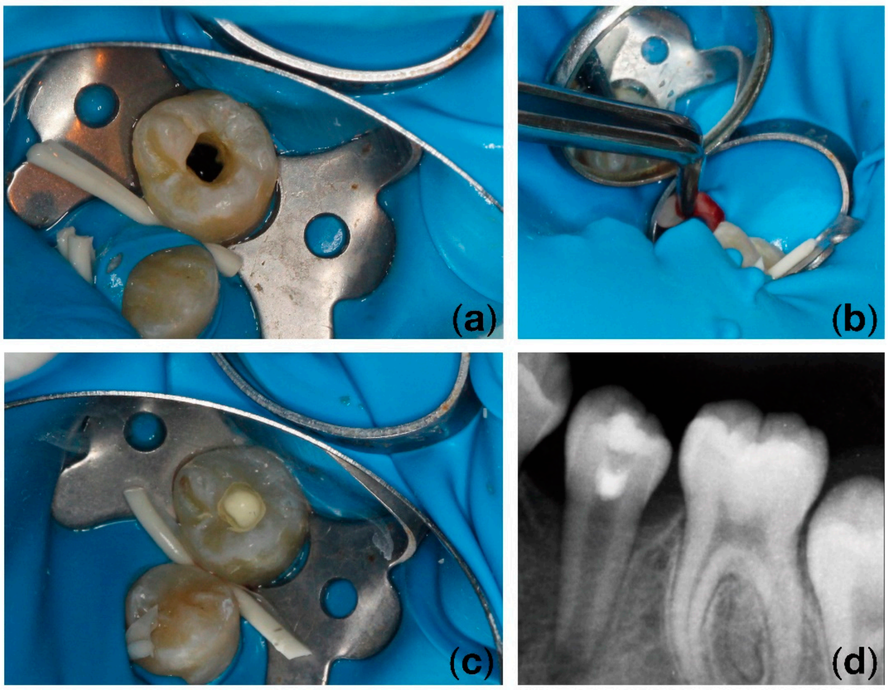

Figure 4. The process of clinical revascularization. (**a**) The apical foramen under the microscope; (**b**) CGF membrane was placed into the canal; (**c**) 3-mm-thick layer of white MTA was placed directly over the CGF matrix; (**d**) MTA at CEJ level.

3. Results

At the 3-month follow-up, there was no history of pain or discomfort, and clinical examination showed that no sensitivity was present to percussion and palpation. Tooth discoloration was observed circumferentially at the level of the CEJ. The radiographic examination revealed complete healing of the periapical lesions. At the 6-month, 11-month, 22-month, and 39-month follow-ups, the patient continued to be asymptomatic. The radiographs showed an indication of continued root development and closure of the root apex (Figure 5).

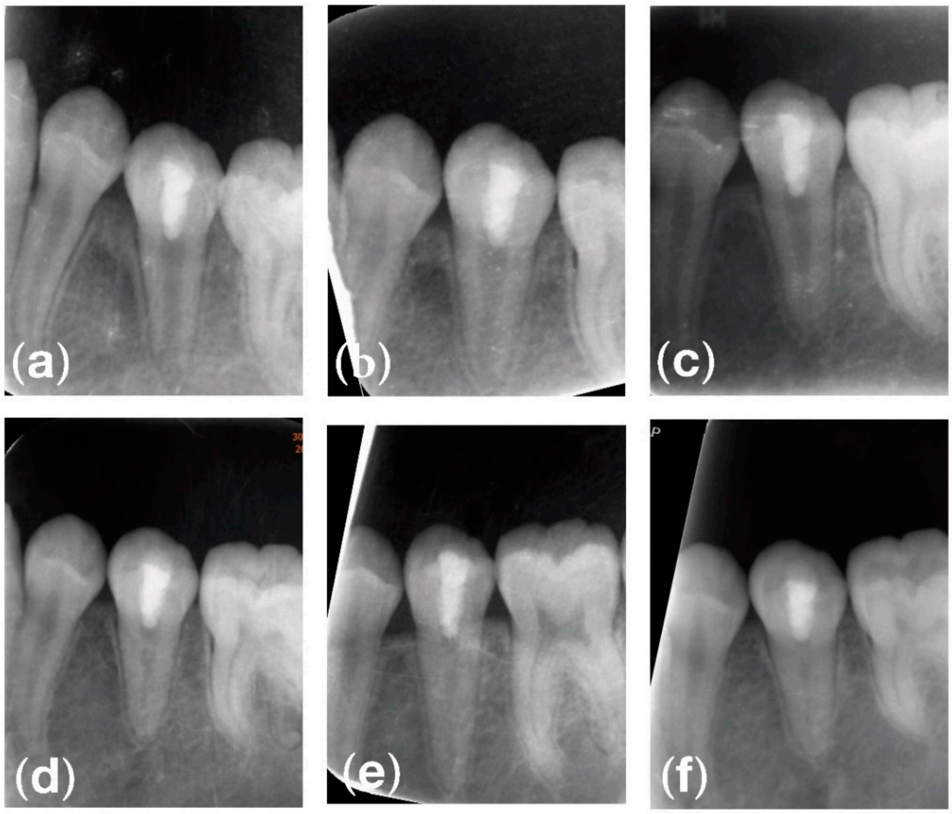

Figure 5. Long term follow-ups. (**a**) 3-month follow-up; (**b**) 6-month follow-up; (**c**) 11-month follow-up; (**d**) 22-month follow-up; (**e**) 39-month follow-up; (**f**) and 53-month follow-up.

At the latest follow-up visit at 53 months, the tooth remained asymptomatic and fully functional. Additionally, it responded positively to both electric pulp testing and cold testing. We replaced the GIC with composite resin in tooth 35. The patient felt sensitivity when we prepared the cavity, which might indicate that this tooth had vital tissue. The periapical radiography revealed obvious apical closure and thickening of the dentinal walls.

4. Discussion

Under certain circumstances, revascularization may still occur in the space of the pulp cavities [13]. Revascularization of immature teeth with apical periodontitis depends mainly on: (a) an effective coronal seal; (b) a matrix for tissue ingrowth; and (c) thorough disinfection of the root canal [14].

Current revascularization commonly uses provoked apical bleeding into the pulp space as a possible source of stem cells and also for creating a blood clot [15]. It provides an autologous scaffold that contains the growth factors and has the advantages of low cost, clinical simplicity, and a short setting time [16]. However, invoking adequate apical bleeding may not always be possible, which may be related to unfavourable outcomes [17]. An alternative to creating a blood clot is the use of platelet-rich plasma, platelet-rich fibrin, or other autologous platelet concentrates [18]. CGF, the latest generation of autologous platelet concentrates, was first developed by Sacco in 2006. It has been widely used in the oral field as a barrier membrane, reservoir, or bio-scaffold [19]. Compared with platelet-rich plasma and platelet-rich fibrin, CGF is prepared by a simplified and optimized variable speed centrifugation procedure, which increases the probability of releasing various cytokines after rupture. CGF is also superior in degradation performance, strong clinical operability, and promotion of tissue healing [20].

NaOCl possesses favourable antimicrobial and cytotoxic effects. Lower concentrations of NaOCl are commonly used because of the fear of inadvertent extrusion into the periapical tissues [21]. Diogenes et al. demonstrated that only 34% of the published pulp revascularization cases used full strength NaOCl (5–6%), which may be a reflection of operators' anxiety when treating immature necrotic teeth [22]. The selection of NaOCl concentration reflects the need for a balance between adequate disinfection and tissue preservation [23]. Therefore, the steps of revascularization procedures will be a compromise that allows for sufficient disinfection with minimum structural damage to cells. Lower concentrations of NaOCl (up to 3%) are advised by AAE. In this case, we further reduced the concentration of NaOCl and selected the concentration of 0.5% NaOCl because low concentrations (0.5 to 1%) of NaOCl can reduce its irritation, corrosiveness, and cytotoxicity to tissues [24].

NaOCl irrigation alone is not enough to reliably create the necessary conditions for revascularization of infectious and necrotic teeth [25]. Furthermore, there are still some limitations to syringe irrigation in addition to using a high volume of irrigate (approximately 20 mL) for more than 20 min, including the existence of the stagnation plane, difficulty in irrigating infiltration, and the disadvantages of laminar flow being able to impose shear stress on the canal walls and biofilm [26].

P. McCabe et al. reported that ultrasound-assisted irrigation was used to perform revascularization in a single visit [27]. In this case, we used an Er: YAG laser with a wavelength of 2940 nm to assist with the 0.5% NaOCl irrigation. Er: YAG laser is commonly used in root canal therapy to achieve better clinical effects [9]. The high absorption of the Er: YAG (2940 nm) by water, coordinated with the high peak power generated by a short pulse (50 μs), leads to the rapid formation, expansion, and subsequent collapse of a bubble [28]. The collapsing bubble then initiates the growth of secondary small cavitation bubbles, inducing turbulent fluid movement throughout the canal, which generates strong shear stresses against the root canal walls and improves the efficacy of debridement [9].

PIPS is a novel laser irrigation technique used in combination with an Er: YAG laser, which is based on photoacoustic and photomechanical effects (with the tip only in the chamber, without needing to reach the root apex), making it different from other irrigation techniques [29]. PIPS improves clinical effects for the following reasons: (1) in immature permanent teeth, bacteria may penetrate more dentinal tubules and advance deeper [30]. The area of Er: YAG laser-activated penetration is significantly larger than that of the other methods [29]. (2) The cumulative fluid movement generated by PIPS appears to be sufficient for the irrigation of lateral canals [19]. (3) The existence of a smear layer on the apical part of root canal walls may potentially lead to the failure of regenerative endodontic treatments [31]; meanwhile, PIPS is significantly more effective in removing dentine debris from this part of the root canal [8]. (4) PIPS exhibits lower extrusion [9], which suggests the safety of the Er: YAG laser in root canal disinfection. For immature teeth with open apices, irrigation may have risks for apical irrigant extrusion, thus damaging the apical papilla. A recent laboratory study suggested that an Er: YAG laser could be used in teeth with open apices for improving disinfection and cleaning of the root canal without risk of apical extrusion when used cautiously [7].

In immature permanent teeth undergoing revascularization, there is a 50% chance that the pulp will regain its vitality [32]. In our case, after 53 months, the patient responded positively to both pulp electrical testing and cold testing. Chueh et al. [33] reported the resolution of apical radiolucency within an average of 8 months and "nearly normal" root development within an average of 16 months after revascularization. In our case, the apical radiolucency had disappeared at the 3-month follow-up, and apical closure was approximately completed at the 11-month follow-up. In the last follow-up visit, we observed X-ray evidence of continued root development including the obvious increase in root thickness and length. At the same time, the teeth continued to erupt to the occlusal plane. The patient felt sensitivity when we prepared the cavity, which might indicate that there was vital tissue in the root canal space [34].

5. Conclusions

In this case report, 0.5% NaOCl was used as the only disinfectant assisted by Er: YAG laser irrigation to achieve revascularization of periapical periodontitis with CGF and thereby obtain apical closure, root development, and maintenance of physiological function. To the best of our knowledge, this is the first case report about the use of Er: YAG laser-assisted irrigation in revascularization. Er: YAG irrigation is an efficient root canal disinfection protocol with the advantages of easy operation and minimal risk, which might be applicable to revascularization of necrotic immature permanent teeth. However, further high-quality clinical studies are needed to develop strong scientific evidence to better support this statement.

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Institutional Review Board Statement: This case report was approved by the Ethics Committee of School & Hospital of Stomatology, Wuhan University, and was conducted in adherence with the tenets of the Declaration of Helsinki.

Informed Consent Statement: All procedures performed in studies involving human participants were in accordance with the ethical standards of Medical Ethics Committee of Hospital of Stomatology Wuhan University (approval #2021-B27). Written informed consent was obtained from the patient for treatment and publication of this case report and any accompanying images.

Data Availability Statement: Not applicable.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

Er: YAG	Erbium: yttrium–aluminium–garnet
NaOCl	sodium hypochlorite
CGF	concentrated growth factor
MTA	mineral trioxide aggregate
PIPS	photon-induced photoacoustic streaming
CEJ	cement–enamel junction
GIC	glass-ionomer cement

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