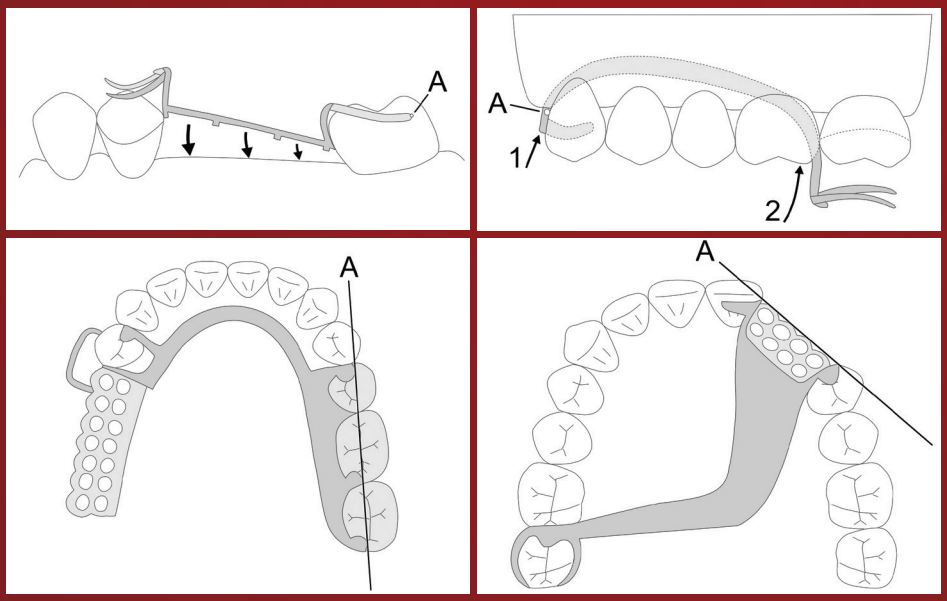
The Academy of Prosthetic Dentistry R.O.C., Taiwan

Journal of Prosthodontics and Implantology



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Journal of Prosthodontics and Implantology

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Journal of Prosthodontics and Implantology

Editorial

We are thrilled to announce that our journal has continued to provide high-quality content to our readers despite the ongoing challenges presented by the COVID-19 pandemic in 2022. In this volume, we feature two case reports and one case series, which offer unique insights and perspectives on clinical practice, patient care, and management.

In addition to the case reports, we have added a review article, which covers the types of clinical application of rotational path removable partial dentures, to keep our readers informed of the latest advances. We believe that this combination of case reports and review articles is essential for providing a comprehensive and engaging publication that reflects the diverse and evolving landscape of the dental industry.

Our team has worked hard to overcome the obstacles presented by the pandemic and provide a platform for the dental community to share their knowledge, insights, and experiences. We remain committed to maintaining our standard of high-quality content and welcome feedback and suggestions from our readership as we continue to navigate the ever-changing landscape of the prosthodontic industry in Taiwan.

Sincerely,

Li-Deh Lin

Li-Deh Lin, Editor-in-Chief

The Academy of Prosthetic Dentistry R.O.C., Taiwan

Case Report

Management of Fractured Implant Abutment Screws: A Case Series

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Abstract

Implant abutment screw fracture is a rare occurrence that can introduce complications and challenges for clinicians. This case report describes three abutment screw fractures that were treated using different strategies: screw fragment retrieval combined with the fabrication of a new prosthesis; the customized casting of a metal post and core with crown fabrication, and the removal and replacement of the implant fixture. The retrieved screw fragment was examined by scanning electron microscope, and a flowchart of the treatment protocol is also presented.

Key words: implant screw fracture, abutment screw fracture, SEM, fractured screw retrieval

Introduction

Osseointegrated implant therapy is a broadly used and promising approach in modern dentistry, with single-implant 5-year survival ranging from 95.9% to 99.1% and 10-year survival ranging from 93% to 95.2% [1-3]. However, implant restorations can be associated with both biological complications, such as peri-mucositis or peri-implantitis, and mechanical complications, such as porcelain fractures, the loosening or fracturing of the abutment screw, the fracturing of the abutment or superstructure, or crown loosening and loss[3-5].

Among all known mechanical complications, abutment screw loosening is the most common complication, with an incidence of 5.8% to 12.7% after five years of follow-up[3,6,7]. Screw loosening can be managed by retightening the screw[8]; however, frequent screw loosening may indicate overloading, which can eventually lead to abutment screw fracture or implant fracture[3,6,7]. Abutment screw fracture has a cumulative rate of 0.18% to 0.35% during the 5 years period following implant placement[3,7]. Although abutment screw fracture is rare, removing fracture fragments can be challenging or unachievable. The retrieval of the remaining screw fragments may also cause damage to the inner implant surface or the implant structure, impeding further prosthetic prefabrication.

A decision-making tree presented by Mizumoto et al. in 2018 discussed three different strategies for managing broken screws[9]. The first strategy is to retrieve the fragments and restore the prosthesis. The second strategy is to cast a customized post and core, followed by crown restoration using a conventional

crown protocol. The third strategy is to remove the implant fixture entirely, followed by replacement with a new implant. This study presents three abutment screw fracture cases treated with each of these recommended strategies.

Case 1

An 85-year-old woman received implant placements at sites 45 and 46. After ten years of use, the abutment screws fractured in both implants, with porcelain fractures on the buccal and occlusal surfaces of the porcelain fused to metal crowns (Figure 1a). Both implants were 4.1 × 10 mm in size with an external hexagon connection (Biomet 3i). Mild inflammation was observed around the implant fixture. The periapical film showed minor bone loss to the first fixture thread, with stable marginal bone levels.

The patient has bruxism, with severe attrition of the teeth. Indications of clenching were observed on the tongue border, and hyperactivity in the masseter muscle was also indicated. The patient presented with fremitus in all upper teeth during occlusal contact, indicating excessive biting force.

On the day of surgery, a mid-crestal incision and flap evaluation were performed to reveal the implant fixture. The screw fragment in the implant at position 46 was loose. After cleaning debris with a scaling tip, a drill in the retrieval kit was used to remove the fragment without further damage (Figure 2a). The screw fragment associated with the implant at position 45 was tight. The use of probes and ultrasonic scaling was attempted but failed, followed by the use of the retrieval kit. A guide sleeve was stabilized on the external connection of the fixture, and an anti-rotation drill with an oblique end was inserted directly onto the fragment. Reverse rotation was applied while cautiously applying pressure to the fragment. The piece rotated for 1 mm but again became lodged in the fixture. Finally, a #311 carbide bur was inserted to drill the fragment and apply vibration to the piece, with irrigation to prevent high heat. The fragment was ultimately loosened and removed (Figure 2b).

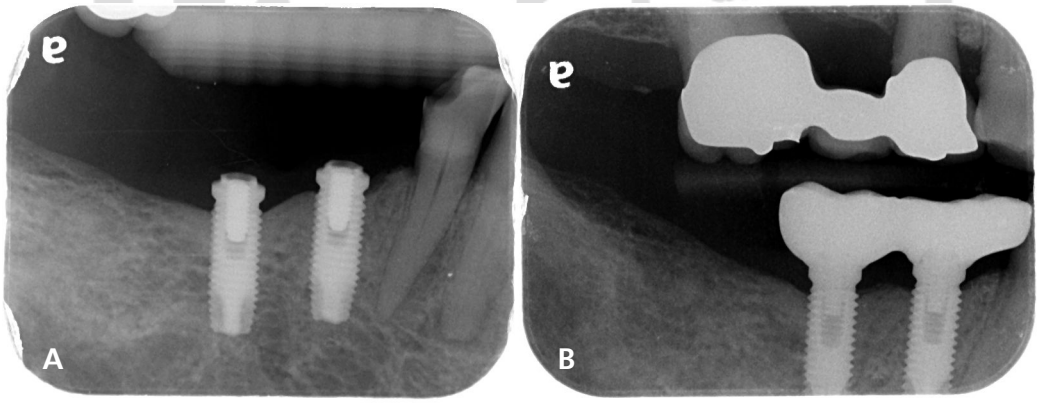

Figure 1. (a) Fractures of the coronal segments of the abutment screws at positions 45 and 46. (b) Fabrication of splinted metal milling crowns

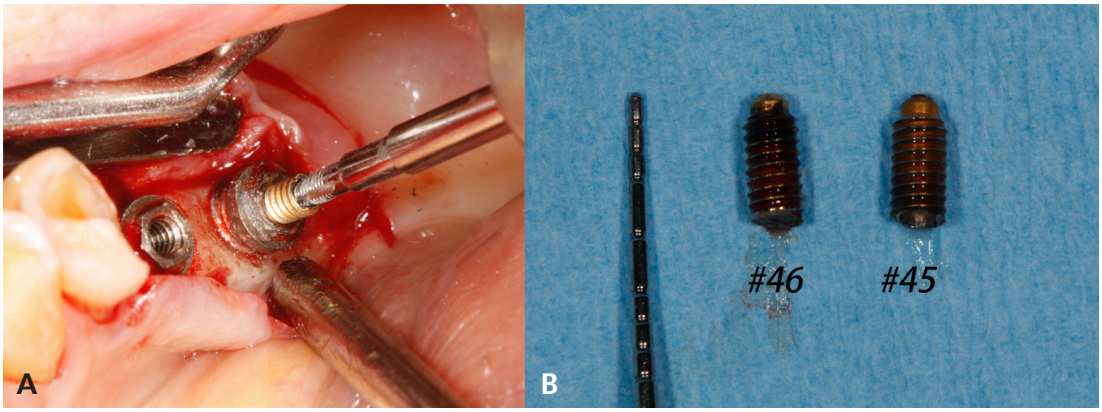

Figure 2. (a) Removal of the fractured screw at position 46 with the assistance of a retrieval kit. (b) Photos of the screw fragments. The fragment retrieved from position 46 has debris between the screw threads and may have loosened prior to fracture. The fragment retrieved from position 45 has clean threads. The fractural surface of the fragment retrieved from position 45 was damaged during drilling.

The implant fixtures at positions 45 and 46 were evaluated, revealing mild wear at the connection site. After discussion with the patient, screw-retained, full-metal, splinted crowns were placed (Figure 1b). Occlusal contact with teeth 45 and 46 during excursive movement was eliminated, and an occlusal splint was delivered as a night guard.

The fractural surface of the screw retrieved from tooth 46 was examined under a scanning electron microscope (SEM), and the surface of the screw from tooth 45 was damaged during removal (Figure 3a–d).

Case 2

A 59-year-old man suffered from an implant abutment screw fracture at tooth 16, and a previous attempt to remove the fragment failed (Figure 4a). The fragment could not be grasped after loosening, and the internal thread was damaged. The patient was diagnosed with hyperactive masseter muscle and clenching habits. No signs of bruxism were found. Anti-rotational grooves were made on the inner surface of the fixture. A customized post and core were casted using an indirect method and cemented to the implant fixture. Further fabrication of the splinted 15 and 16 crowns was performed using a conventional prosthetic protocol (Figure 4b).

Case 3

A 40-year-old woman presented with an implant-supported fixed prosthesis at the lower left first molar (Ankylos, Dentsply Sirona). After five years of use, the implant crown fractured at the abutment neck due to frictional resistance in the conical connection. The fractured abutment remained tight after the screw fragment was retrieved (Figure 5a). The implant fixture was removed, and guided bone regeneration was performed. A new implant fixture (Institute Straumann AG) was inserted after six months and has since remained stable (Figure 5b).

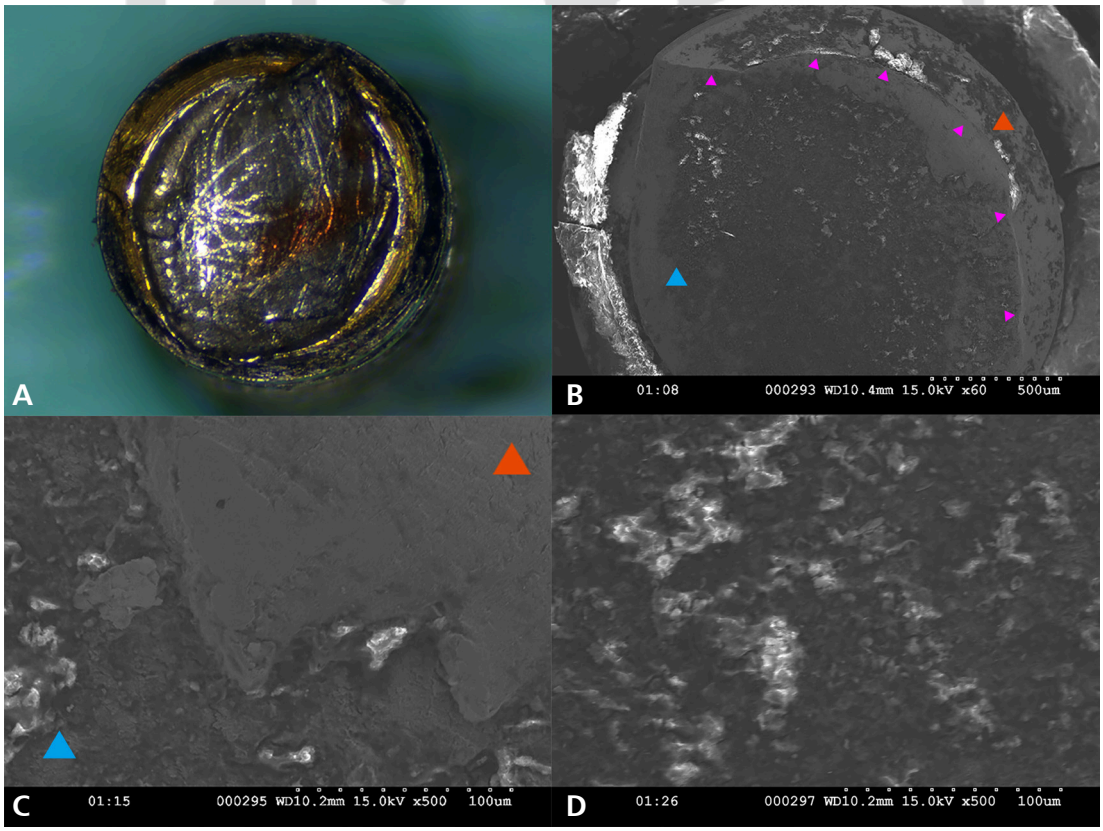

Figure 3. (a) Image of the fractural surface from the coronal portion of the screw retrieved from position 46 under a light microscope (4×) reveals scratches caused by the ultrasonic tips. The fractural surface has a sharp edge. (b) The fractural surface of the screw retrieved from position 46 at 500× using a scanning electron microscope (SEM). Smooth (red) and rough (blue) portions reveal the 2 phases of the fracture. The smooth surface characterizes the start of the fracture; chewing motions smoothed the surface until the fracture of the whole screw occurred, resulting in the formation of a rough fractural surface. (c) Smooth (Red) and rough surfaces (Blue) under 3000× SEM. (d) Coarse particles of the rough surface under 4000× SEM.

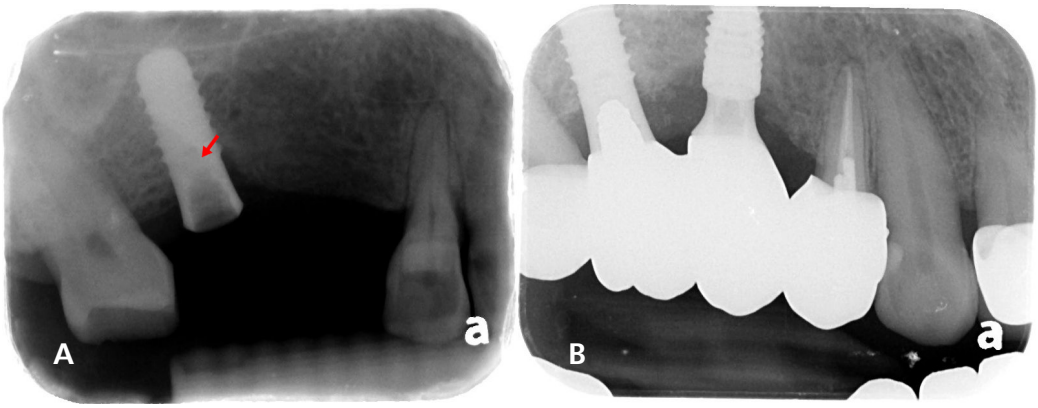

Figure 4. (a) Damaged internal thread. The red arrow shows the unretrieved screw fragment. (b) A post and core were cast using an indirect method, and a splinted prosthesis was placed at positions 15 and 16 implants.

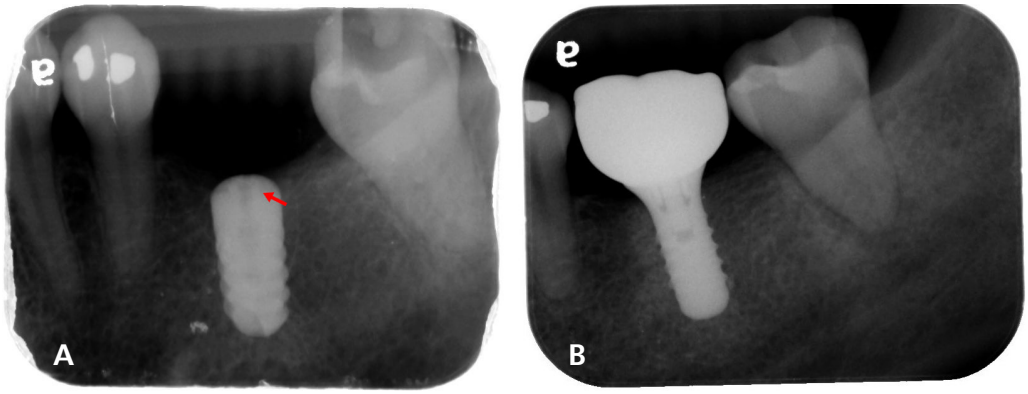

Figure 5. Removal of the implant and reimplantation. (a) The screw was successfully retrieved, but the fractured abutment remained (red arrow). (b) Removal of the implant fixture and reimplantation.

Discussion

The incidence of abutment screw fractures is low, occurring at a rate of 0.18% to 0.35% during the five years following placement. A study by Kim et al.[10] found that most screw loosening and fractures occurred in the posterior crowns, with an incidence of 1.6% for anterior crowns, 8.9% for posterior crowns, and fractures occurring most commonly in the mandibular first molar and maxillary central incisor[11-15]. The 3 cases presented in our study included fractures in the maxillary and mandibular first molar and second premolar.

Abutment screw fracture may be caused by biomechanical overloading, improper placement techniques, or a non-passive fit prosthesis. In addition, functional cyclic loading with extended periods of clinical use, repeated retightening of loose screws, poor design of the fixture–abutment connection, inadequate tightening, screw joint movement, or metal fatigue after screw loosening can also induce fatigue fractures[16].

Implant overloading can be multifactorial, and the design of the occlusal scheme plays an important role. The loading on the abutment and screw increases as the load becomes more inclined in both platform–switch or internal connection implants[17] and minimizing off-axial loading can reduce the risk of screw loosening. The splinting of implant crowns is another influencing factor, as splinted implant crowns provide a more even distribution of stress loading, which may reduce the risk of screw loosening[18]. In a split-mouth study of 15 patients, screw loosening was only observed in non-splinted, single implants, with an incidence of 5 of 15 implants[19]. However, no significant differences in the incidence of prosthetic complications were observed between crown–implant ratios (C–I ratio) of >1.5 and <1.5 in clinical studies [20]. The diet and parafunctional activities of the patient can also influence the load placed on the implant[21], and other factors, such as opposing dentition and prosthetic materials, should also be considered in the risk assessment.

The connections between prosthetics and dental implants can be classified into three groups: external connections, internal connections, and conical connections[22]. Different connections

can influence stress distribution. With external connections, occlusal stress is transmitted to the screw and joint of the connection, and studies have reported a higher incidence of screw loosening and fracture in implants that use an external connection compared with internal or Morse-tapered connections[23,24]. However, some studies have also presented conflicting results, showing no significant differences between the different connections[25]. With conical connections, the tapered contact between the implant and the abutment interface forms a strong friction resistance force that retains the abutment position even after screw removal[26]. If the abutment fractures, this friction makes removal more difficult. The development of a pertinent appliance is critical for the treatment of conical connections.

The depth at which the fracture occurs also influences screw retrievability. Fractures that occur closer to the platform or are more coronal are easier to access. In cases fractured at the apical third, poor visualization and difficulty accessing the fragment can increase the risk of damaging the screw threads. Even after loosening the fragment, the ability to grasp and remove the fragment may be limited by available instruments.

In 2018, Mizumoto et al.[9] suggested that fragment retrieval methods were associated with different levels of risk. The low-risk method involves using basic instruments and scalers, such as rigid explorers and ultrasonic tips, preventing damage to the internal surface of the fixture. The moderate-risk method involves the use of rotary instruments to remove the fragment, including customized drills or commercial retrieval kits that utilize low-speed rotary instruments, such as the Fragment Fork (Astra Tech; Dentsply Sirona), ITI Dental Implant System (Institute Straumann AG), and IMZ TwinPlus Implant System 1 (Dentsply Sirona). These retrieval kits are specifically designed for fragment retrieval and contain two components: sleeves or cylinders to guide the drills and prevent damage to the internal surface and burs with oblique or specialized tips that can grasp the coronal section of the fragment. If retrieval kits are unavailable, clinicians may fabricate customized burs to match the fractured piece[27] or modify impression posts into specific guide tubes to protect the internal surface[28]. Fragments may also be retrieved by drilling freehanded; studies have recommended placing a notch on the screw fragment, away from the center, to form a lever with which to rotate the fragment[12] or drilling the whole fragment until it loosens. Some cases described the use of re-tapping tools to re-tap damaged threads and the replacement of the old prosthesis using new screws that provide larger preloads[29].

If the fragment is unremovable or the internal thread is damaged, the last resort is to modify or remove the implant. Removing the old implant fixture and reimplanting a new fixture may restore implant function and is associated with the most predictable outcome. Other common treatments include submerging the implant fixture or casting a customized post and core for the remaining fixture. A customized metal coping may be fabricated directly or indirectly after cementing the metal post to the implant fixture. A prostheses can then be fabricated following conventional protocols, and the implant may be reused[30]. However, disadvantages include further cement wash-out, reduction in the strength of the remaining walls, and increased risk of implant fracture from a wedging effect, depending on the amount of preparation necessary[15].

Some studies have applied different methods to reuse implant fixtures. One study presented the conservative restoration of an implant transfer cap screw using a build-up crown with a resin composite [16]. Another study replaced the prosthesis in the implant fixture using shortened screws, in which the previously fractured screw fragments was pressed apically, providing room for the placement of a new, shortened screw[15].

Based on the 3 cases described in the present study, we can conclude that factors influencing the outcomes of fractured abutment screws include the connection type, the depth of the fractured screw, and whether the screw is tight or loose. Fragments that are more coronal and looser are easier to retrieve. Conical connections are associated with a large degree of frictional resistance, introducing increased difficulty when attempting to remove a fractured abutment fragment. The estimation and management process for determining how to approach a fractured screw retrieval is presented as a flowchart (Figure 6). The design of the implant prosthesis should be evaluated to avoid factors that cause overloading, and close follow-up is necessary for high-risk patients.

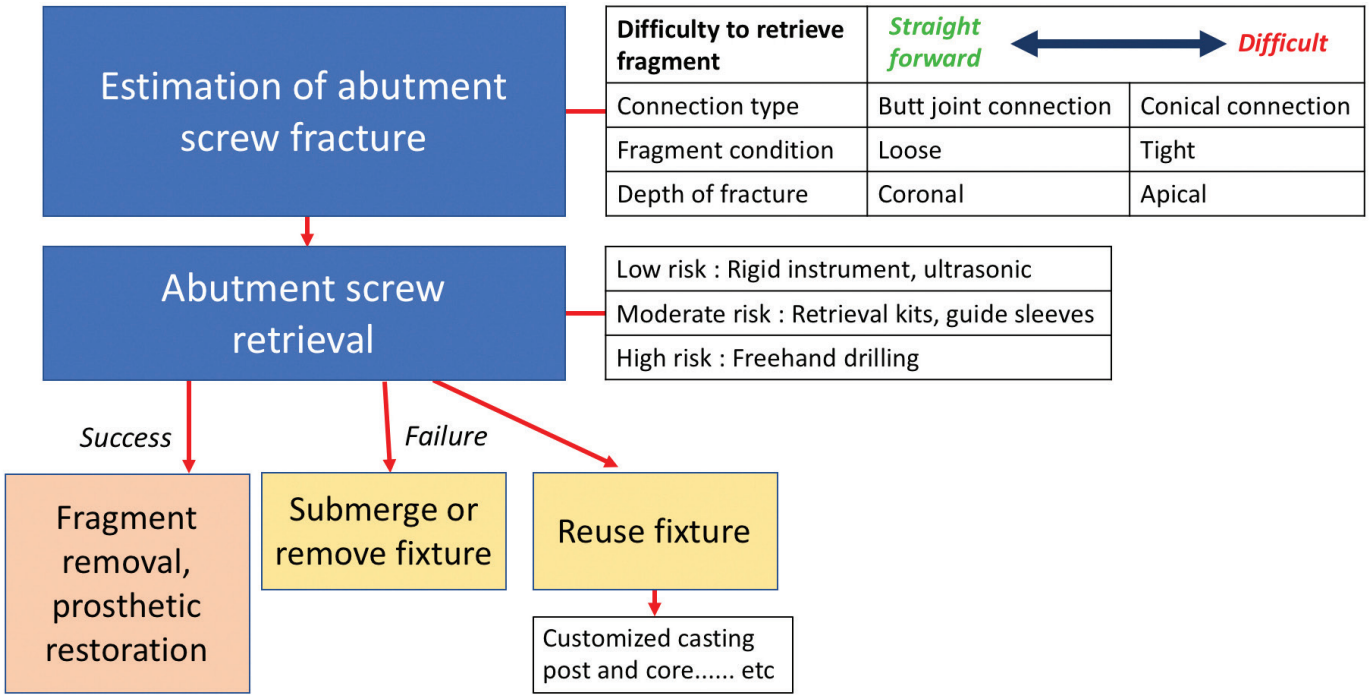

Figure 6. Flowchart of fractured abutment screw retrieval evaluation.

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Case Report

Literature review and application of pre-treatment survival rate assessment of abutments of removable partial dentures

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Abstract

In order to obtain a successful prosthetic outcome, we need to consider the prognosis of each abutment tooth. Because a poor prognosis of abutments will make the removable partial denture (RPD) failure, it is important to check each abutment tooth condition to prolong a longevity prosthesis. This article reviews the current understanding of the relationship between the prognosis of abutments and their potential impact factors for achieving clinical goals, and a clinical case for introducing the application of pre-treatment survival rate assessment of abutments of a removable partial denture.

Key words: abutment, prognosis, removable partial denture, survival rate assessment

Introduction

The abutment teeth may be prepared to provide support, stabilization, reciprocation, and retention for the removable partial denture(RPD)[1]. Vermeulen et al. reported of taking abutment retreatment as a failure criterion, 40% of the conventional RPDs survived five years and more than 20% survived ten years; taking replacement or not wearing the RPD as failure criteria, the survival rate was 75% after five years and 50% after ten years[2]. Sayaka Tada et al. reported, the 5-year survival rate of abutment teeth was significantly lower (86.6%) than non-abutment teeth (95.8%) for patients wearing RPDs[3]. Therefore, the abutment teeth problems influenced the survival rate of RPD much more. The abutment teeth of RPDs were reported to be at higher risk of periodontitis[4,5], dental caries[6,7] and root fracture[8] than other teeth. Longitudinal studies have also shown that RPD abutments were at an increased risk of loss[9,10.] When an original abutment is lost, it is extremely difficult to effectively modify the removable partial denture to use the next adjacent tooth as a retaining unit. Therefore, knowing the prognosis of each abutment tooth before the treatment starts is quite important. Some factors may affect the abutments' survival rate: periodontal support, endodontic treated tooth, and crown-root ratio factor.

Besides the above three factors, Sayaka Tada et al. evaluated 147 patients who were provided with 236 new RPDs ; the 856 abutments of these RPDs were analyzed and followed up for five years. The results showed that the abutment survival rate

was significantly influenced by the crown-root ratio, root canal treatment, pocket depth, and type of abutments[3]. Estimating individualized risk and benefit for each residual tooth is important to clinical decision-making. These influence factors will discuss more below.

Crown-root ratio

The Crown-root ratio is served as an aid in predicting the prognosis of teeth[11]. A ratio of 1:2 was considered ideal[12], and a crown-root ratio of 1: 1 was considered mini-mal[11, 13]. A tooth with less bone support has a higher crownroot ratio, there-fore it is less resistant to masticatory loads and lateral force espe-cially when the tooth is an abutment in RPDs[14]. Tada S et al. concluded that, if the opposing prosthesis is tissue supported, then a crown-root ratio greater than 1:1 might be adequate, due to the diminished occlusal forces[15]. In my case an old bridge cantilever of 44-45-X, a crown-root ratio about 1: 1 of 45 and 1: 1.14 of 44 by the periapical film was considered minimal ratio as an abut-ment for RPD (fig.1).

Grossmann Y et al. reported that reducing the crown to 1 to 2 mm above the free gingival margin in abutment preparation for overdentures has the most dramatic effect on the ratio, which can improve the crown-root ratio from 1:1 to 1:2 or 1:3[11]. The decrease in crown height shortens the corresponding lever arm length, and therefore, less lateral force is applied to the attachment apparatus, then reducing the possibility of mobility[16]. Renner et al demonstrated that over a 4-year period, 50% of the roots were without mobility, 25% of the roots that were initially mobile exhibited no mobility, and 25% mobility was decreased of these roots[17]. When we increasing the vertical dimension of occlusion for recon-struction would cause an increase in the crown-root ratio, without altering the root support[18]. When teeth were compromised by caries, extensive wear, or trauma, we may take surgical crown lengthening into consideration for rebuild-ing the ferrule effect[19]. Another treatment option: slow orthodontic eruption al-lows the periodontal ligament to repair and the alveolar bone to remodel for preserving the biologic width[18, 20, 21].

Endodontic factor

The 4-year tooth survival following primary or secondary root canal treatment was 95%[22]. However, survival rates for endodontically treated teeth were less than for vital teeth when used as RPD abutments. Pia K. Wegner et al. reported that in case of the 410 abutment teeth of RPD after root canal treatment, the 5-year survival rate was only 51%. The retainer or the clasp of RPD caused more mechanical stress to the abutment teeth, so the risk of tooth fracture increased, if the abutment teeth were endodontically treated[23].

If a tooth with a apical lesion is included into the treatment plan as an important abutment for RPD, we may worry about the survival rate of the endodontic problem. Asymptomatic, functional teeth after initial endodontic therapy of apical periodontitis probably approaches or even exceeds 95%[24]. In the other hand, a symptomatic apical periodontitis tooth after non-surgical root canal treatment, should take the apical surgery into consideration as a treatment option. About the prognosis of apical surgery : 37–91% of teeth can be expected to be healed, while up to 33% can still be healing several years after surgery. 80–94% of teeth can remain in symptom-free function, even if they are not healed[25]. In view of these wide range of the prognosis of apical surgery, we should tell the patient about the possibility of extraction of the abutment tooth and further repair of RPD.

Periodontal factor

McGuire MK et al. reported that, the clinical criteria of "good" are bone loss <25%, probing depth <3 mm, without furcation involvement and mobility. Be-fore prosthodontic treatment, the periodontal condition of a tooth is divided

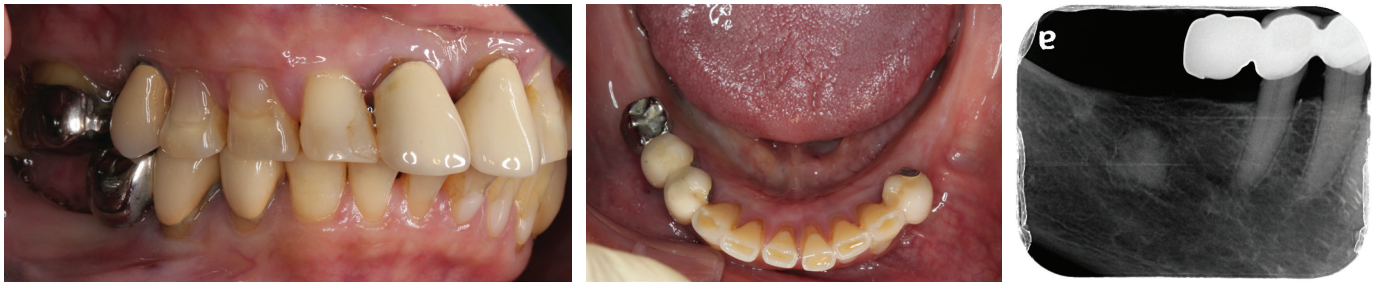

Figure 1. Intra-oral view and periapical film of cantilever 44-45-X

to clinical criteria of "good" , is significantly with lower risk of tooth loss while the follow-up period[26]. Matuliene et al. reported that, probing depth of 5 mm and over represented a significant risk factor, compared with probing depth of 3 mm or less, from multivariate analysis of the association between probing depth and tooth loss[27].

If the abutment tooth is periodontal compromised, we can splint the abutment to the adjacent healthy tooth for extending the abutment lifespan. The definition of "splint" : 1. a rigid or flexible device that maintains in position a displaced or movable part; also used to keep in place and protect an injured part; 2. a rigid or flexible material used to protect, immobilize, or restrict motion in a part[28]. Allahyar Geramy et al. evaluated splinting anterior teeth with periodontal bone loss by 3D Analysis using finite element method. And reported that fixed splinting improves the stress distribution in the surrounding bone and transfers stress from the interdental crest to the apical area of teeth where there is better resistance. Splinting a very weak abutment to an adjacent healthy tooth might not be beneficial. The acceptable crown to root ratio for fixed splinting a weak abutment to an adjacent normal tooth was around 1.65-2[29]. Phoenix RD et al. demonstrated that a tooth that has lost more than 50% of its bone support is a poor candidate for fixed splinting[30].

H G el Charkawi et al. concluded that the reduction of the number of splinted units from three to two resulted in an insignificant increase of stresses recorded, whereas reduction of the number from two to one resulted in a significant in-crease of stresses nine times greater than the three-unit splint val-ues[31]. Therefore, splinting two teeth will achieve the effect of stresses distribu-tion. In my case, due to the sign of the periodontal attachment loss of 45 and crown-root ratio was about 1:1 by periapical film (fig.1), we decided to splint 44 and 45 together during the temporary to permanent period after removing the old bridge cantilever (fig.2 and fig.3).

Rigidity of major connectors and maximum

Figure 2. final impression of 44, 45

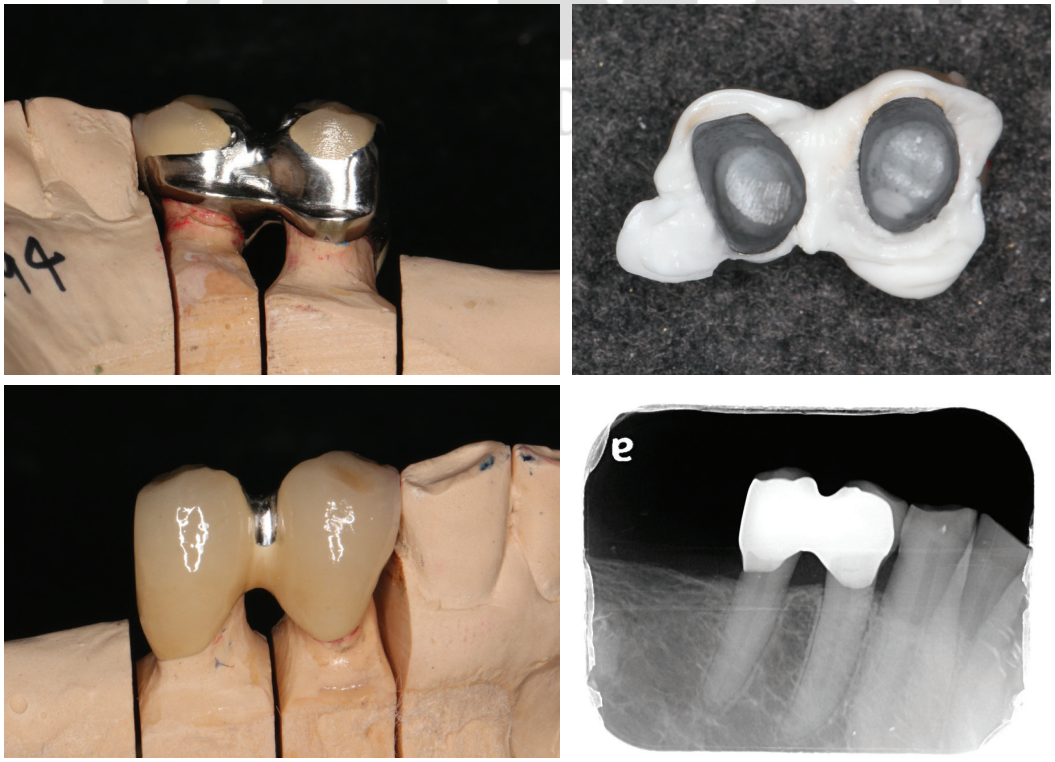

Figure 3. delivery of 44-45 and periapical film after cementation

coverage of denture-bearing areas with denture bases are of great importance in reducing stresses on abutment teeth. Splinting of abutment teeth is indicated when the periodontal support has been reduced or when increased stresses are expected, as in the use of intracoronal attachments[32]. After the teeth are splinted, it will cause inconvenience for the patient to keep good oral hygiene[33]. Furthermore, endodontic complications occur much more in splinted abutments than in non-abutment teeth[34]. These must be taken into clinical considerations.

Sayaka Tada et al. concluded that the abutment teeth bearing rest, clasp, or mi-nor connector of RPD might get more mechanical and bacterial stress then non-abutment teeth, with a higher risk to damage the periodontal tissue[3]. ML Al-meida et al. concluded that abutment teeth with direct retainers had significantly worse plaque index, bleeding on probing and probing depth values, when compared with the remaining teeth. Prosthesis design may play an important role in periodontal status and recommended that the RPD should have a minimum distance from the gingival margin and that good oral hygiene is essential[35].

Maintenance

RPDs compromise oral hygiene with more plaque accumulation and increase loading stress on abutment teeth, could increase the risk for periodontal disease, dental caries and other mucosal diseases[36]. Tada S et al. reported that periodontal maintenance at least once in 6 months had the most favorable outcome. Frequent periodontal maintenance after RPD provision could be effective in preventing further tooth loss[37]. Moreover, the follow up and maintenance of the RPD also important. Because the edentulous ridge keep resorption as time goes on, the RPD may lose the consistent tissue support, then destroy the abutment teeth. As a result, with much more jiggling force on periodontal tissue, higher failure rate and tendency of increasing mobility of that abutment teeth due to occlusal force and denture movement[38].

My case follow up

The removable partial denture was delivered. Due to the maxillary canine were severe worn out(fig.4). The mandibular RPD occlusal scheme was group function. When the occlusion is physiologically healthy, it has been recommended that the existing occlusal scheme be used, either mutual protection or group func-tion[39]. The 3 years follow up of the 44-45 bridge was fine intraorally. The 44 and 45 were without the sign of PDL widening by periapical film. Checking the re-movable partial denture with fit-checker, although with some bone resorption sign, the denture still stays in stable condition intra-orally without

Figure 4. delivery of mandibular RPD

rotation. (fig.5) Evaluation of abutments was performed during maintenance phase as (Table 1).

Table 1. abutment of 44-45 evaluation in 3 years follow up appointment

	Good	Fair	Poor
Crown-root ratio		√	
Endodontic factor	√		
Periodontal fac-tor		√	
Maintenance		√	

Conclusion

We get the point of the ideal criteria of abutment teeth, and pre-treatment sur-vival rate assessment was done of each tooth well. In spite of following the con-clusions of previous published papers, to keep the tooth or not as the abutment may not be too difficult for us to making decision while treatment planning. But the patient's teeth will not all be kept in good oral hygiene condition, regular follow-up and maintenance are much more important in my case.

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Case Report

Forced eruption in esthetic zone from the prosthetic point of view: A case report

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Running title: Forced Eruption in esthetic zone

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Abstract

Orthodontic extrusion is a common technique to manage a complicated crown-root fracture for re-establishing biologic width of the tooth and elevation of the fractured margin to provide proper ferrule for the crown restoration. However, ill-controlled orthodontic extrusion force on the tapered narrow roots sometimes could induce facial tipping force, and thus cause iatrogenic gingival recession and root dehiscence. This case report describes a simple manner to avoid facial tipping force by using a provisional crown with an additive contour at the facial gingival level to reduce the risk of this complication. The lingualized vector force not only preserves the precarious labial bone plate of the traumatized root but also creates a restorative space which shall minimize the needs of tooth reduction for the crown restoration.

Key words: orthodontic extrusion; forced eruption; fiberotomy; complicated crown-root fracture; biologic width; ferrule effect

Introduction

The complicated crown-root fracture is common in accident. Literatures have shown several modalities to solve the problems that may be encountered. In which, how to manage the traumatized tooth in esthetic zone is really a challenge. The prognosis of the traumatized tooth is majorly based on the position of the fractured line and the future role of the tooth in function and esthetics. In general, re-establishing biologic width and creating sound restorative ferrule of the teeth are mandatory to restore the fractured roots. Clinically, there are three ways to relocate the fracture line, including orthodontic extrusion, crown lengthening procedure, and surgical extrusion[1-3].

As concerns of soft tissue and hard tissue profile in esthetic zone, orthodontic extrusion is the most common way to apply on the fractured anterior teeth. Orthodontic extrusion, also known as forced eruption, was first introduced to change the bony topography around teeth. It was found that periodontal angular bony defects could be improved and even eliminated by orthodontic movement of the tooth [4,5]. Further, soft and hard tissue augmentation was introduced to prepare the recipient dental implant site using orthodontic extrusion of the hopeless

roots [6-8]. However, orthodontic forced eruption with the straight-wire appliance in implant site development resulted in favorable increase in the heights of the palatal and proximal alveolar bone but significant reduction in the buccal plate height, which inhibited implant placement in 35% of the treated sockets[9].

The mechanical eruption of the tooth involves applying a direct force to the tooth in a specific direction, which creates a tension on the periodontal ligament fibers and leads to new bone formation at the crestal aspect of the alveolar bone. Obviously, the direction of the orthodontic force should be carefully controlled, otherwise iatrogenic complications of gingival recession or even root dehiscence could occur if the orthodontic force tipped facially, which will compress the fragile buccal plate and end up with [7,9-12] instead of bone deposition. This case report aims to provide a simple modality to guide the orthodontic force lingually to ensure labial bone plate preservation by using a modified provisional crown with an over-contour at facial cervical zone. The results of a 14-year follow up are presented.

Case report

A 29-year-old male patient presented with fractured upper central incisors (#11 and #21 in the FDI numbering system) and a scar on the upper lip (Fig. 1A). The patient reported that the teeth were injured 1 week before this visit. His medical history was noncontributory. Intraoral examination revealed that the maxillary right central incisor had an oblique root fracture and the fracture line extended subgingivally at the palatal surface of the tooth (Fig. 1B); and the maxillary left central incisor was suffered from fracture at middle third with fresh scarring tissue surrounding. The fractured line over left lateral incisor (#22) was noted and showed no sign of mobility and positive response to an electric pulp test. A periapical radiograph (Fig. 1D) demonstrated fair bone support of the teeth without obvious crack lines along the roots or alveolar fracture, and the trauma was limited to clinical crown fracture of incisors. The biologic width had been directly violated by the fracture at #11 palatal site (Fig. 1C) and there was inadequate tooth structure to achieve a ferrule effect for the subsequent crown restoration. Both the right and left central incisors received emergency endodontic instrumentation and the pulp chambers were filled with calcium hydroxide and covered by IRM.

For the treatment plan for #21 was easy to reach a consensus, while the treatment of # 11 was more complicated. A number of treatment options were offered. If the patient was willing to keep #11, orthodontic extrusion of the tooth with or without crown lengthening was suggested; otherwise extracting tooth #11 and placing an implant or having a fixed bridge was recommended. Considering the financial and social reasons, the patient opted for the treatment of orthodontic extrusion of # 11 without crown lengthening, and then reconstruction of both #11 and #21 with a fiber post and resin core and a full ceramic crown.

After the patient was treated with dental prophylaxis, both incisors were instrumented under a modified rubber dam isolation, and the endodontic treatment was completed with the

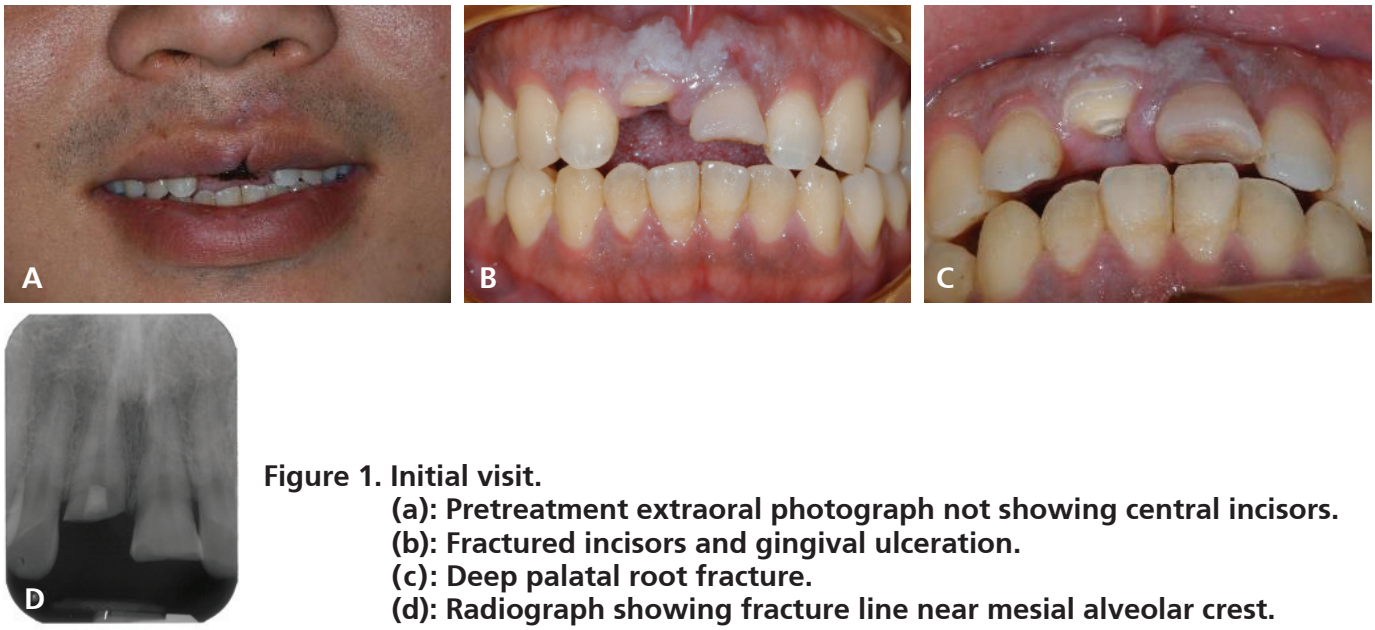

Figure 1. Initial visit.
(a): Pretreatment extraoral photograph not showing central incisors.
(b): Fractured incisors and gingival ulceration.
(c): Deep palatal root fracture.
(d): Radiograph showing fracture line near mesial alveolar crest.

lateral condensation technique (Fig. 2). The teeth were both clinically and radiographically stable at the 3 month follow-up appointment. The gutta-percha filling was partially removed and leaving a 4 mm apical seal. A glass fiber post was placed in the root canal of left incisor (#21) and the restored the crown with composite resin (Fig. 2D).

For the right incisor (#11), electrosurgery (Martin MD 30 Minitom, KLS Martin Manufacturing, FL, USA) was used to exposed the fracture line (Fig. 2E) and a provisional endocrown with a metal post was cemented into the root canal with polycarboxylate cement (HY-Bond, Shofu, Japan), and also radiographically evaluated. The over-contoured profile at the facial gingival level of #11 was created (Fig. 3A), which allow a desirable horizontal vector of force toward the palatal direction and vertical vector of force toward occlusal direction during orthodontic extrusion of the root.

Orthodontic brackets (Standard Edgewise System, Tommy, Japan) were affixed to the teeth from #13 to #22 and intra-arch anchorage was design by splinting the teeth (Fig. 3). The bracket on the #11 was positioned more apically and labially than those on the adjacent teeth, which shall benefit for reduction of the incisal surface during extrusion and avoiding compression on the labial bone plate of the tooth. A 0.016-inch wire (Tommy) was then placed for leveling and alignment of the tooth (Fig. 4).

To minimize gingival downward growth, the supracrestal fiberotomy was conducted with the thinnest probe of electrosurgery before the time starting orthodontic extrusion, and then performed every 2 weeks during the active phase of forced eruption. The procedure of intrasulcular incisions through the junctional epithelium and the supracrestal connective tissue attachment was carried out under local anesthesia. Meanwhile, incisal and occlusal adjustments were performed (Fig. 4C), and the extruded root surfaces were curetted. The patient was prescribed with analgesics for pain relief.

Tooth leveling was completed at 6 weeks of orthodontic treatment. Conservative periodontal surgery was conducted to correct the discrepancy of gingival height, meanwhile supracrestal fiberotomy around the extruded tooth was performed again (Fig. 5). The new provisional crown of #11 was made and splinted with the adjacent #21 for stabilization to prevent relapse intrusion (Fig. 6). Overcontouring modification of the #11 provisional crown at gingival level was performed to accommodate the new gingival embrasure space generated from the erupted tooth, because the narrower root portion of the erupted tooth was exposed. The stabilization period was planned for 4 months. However, the patient

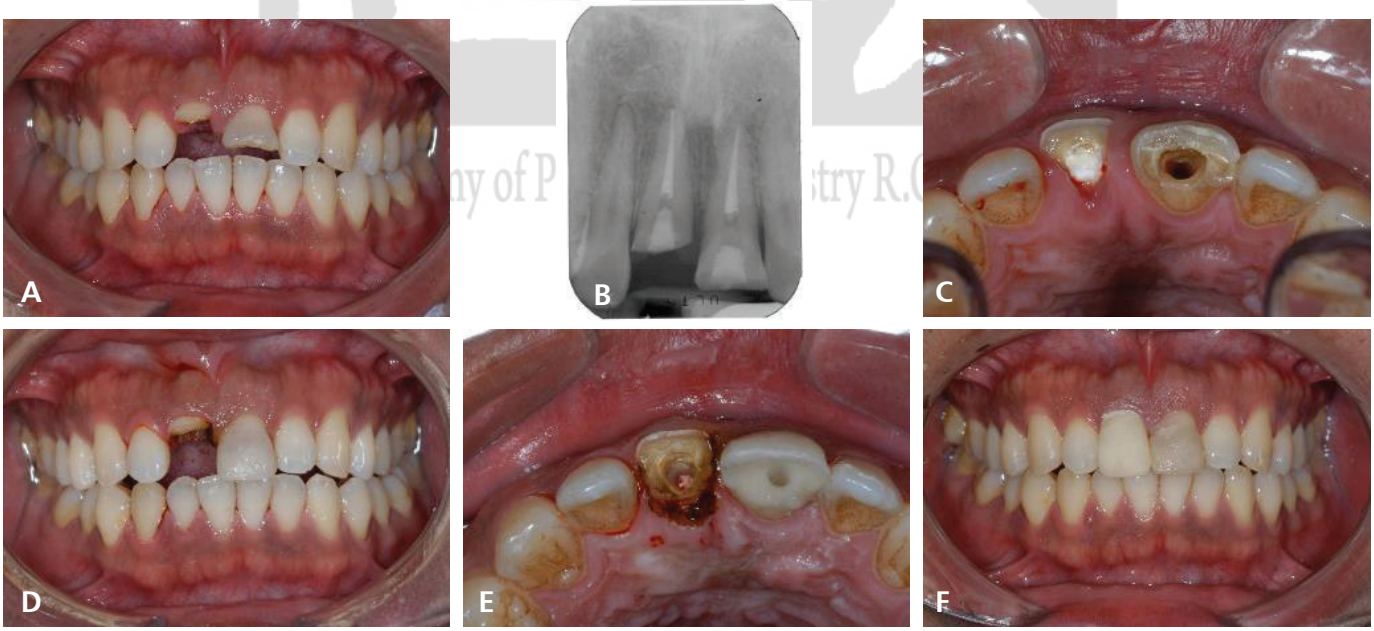

Figure 2. Endodontic treatment and provision crown fabrication.
(a): Healing of gingival tissue.
(b): Radiograph showing completeness of root canal treatment.
(c): Post space preparation for left central incisor.
(d): Delivery of provisional crown for left central incisor.
(e): Electrosurgery to exposure fracture line.
(f): Delivery of provisional crown for right central incisor.

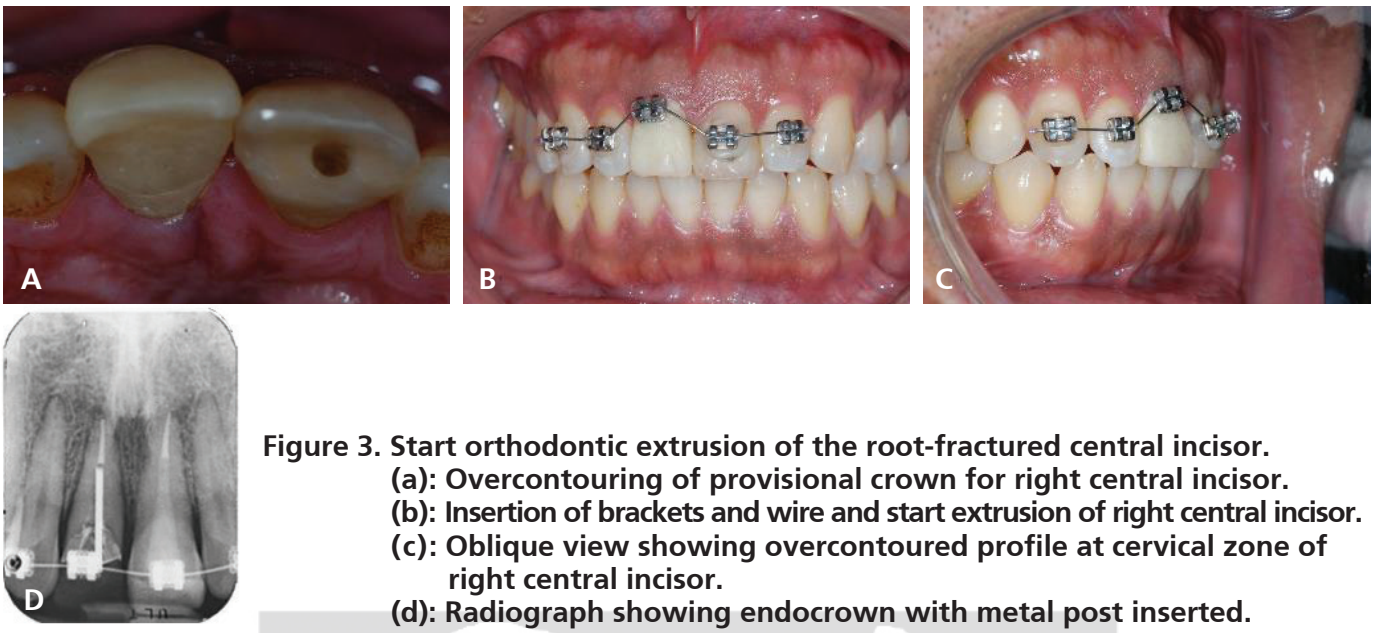

Figure 3. Start orthodontic extrusion of the root-fractured central incisor.
(a): Overcontouring of provisional crown for right central incisor.
(b): Insertion of brackets and wire and start extrusion of right central incisor.
(c): Oblique view showing overcontoured profile at cervical zone of right central incisor.
(d): Radiograph showing endocrown with metal post inserted.

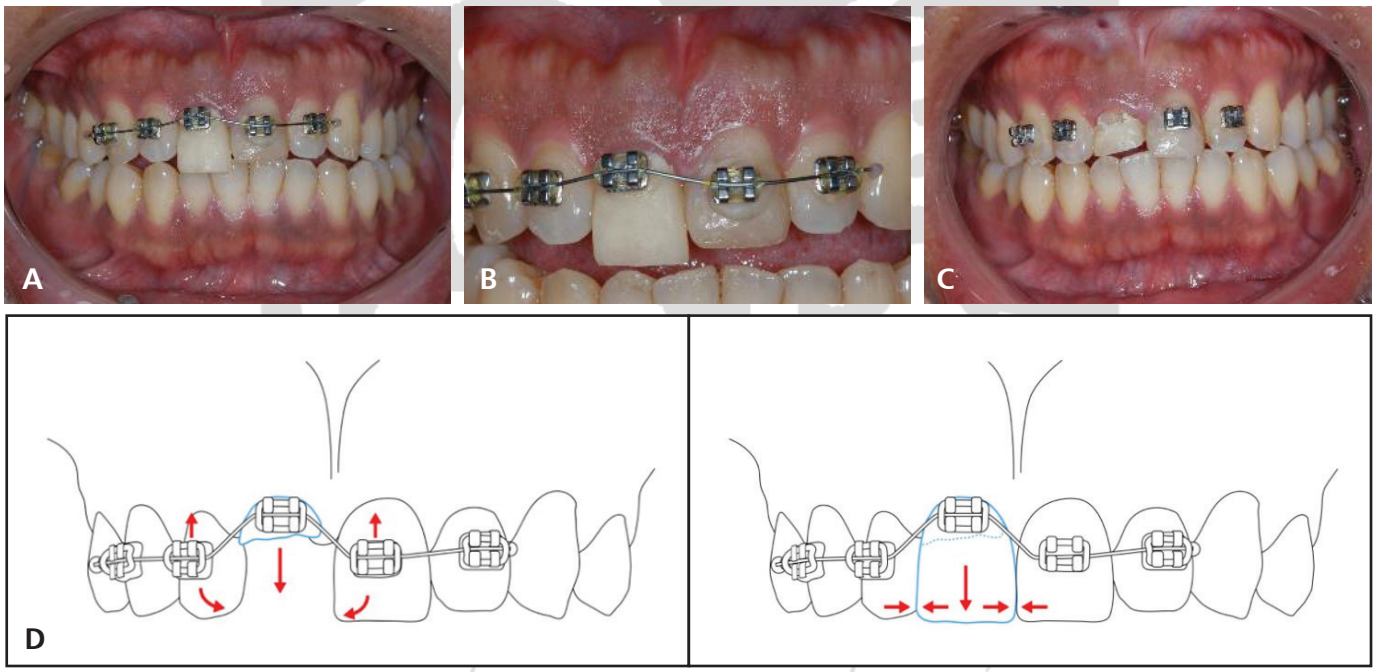

Figure 4. During orthodontic extrusion of the root-fractured central incisor.
(a): Extrusion of the fractured tooth.
(b): Gingival downward growth of the extruded tooth.
(c): Incisal and occlusal adjustment for the extruded tooth.
(d): Temporization of the fractured root providing esthetics and reducing the risk of inward tipping of adjacent teeth during orthodontic extrusion of the root.

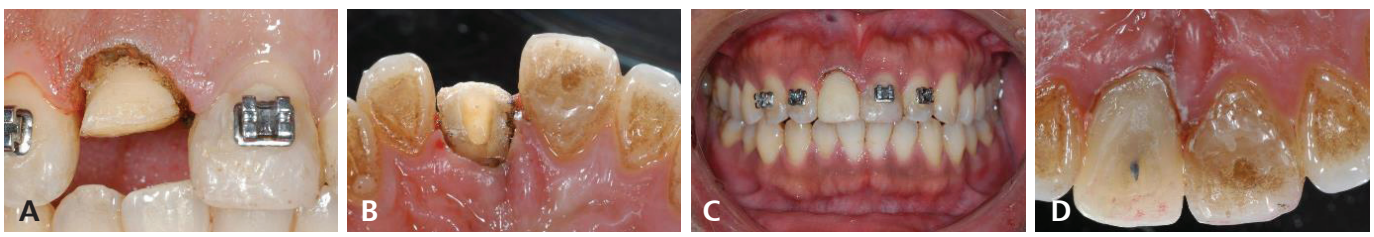

Figure 5. Fiberotomy during orthodontic extrusion.
(a): Facial view of fiberotomy of the extruded tooth.
(b): Palatal view of the extruded tooth.
(c): Facial view of new provisional crown of the extruded tooth.
(d): Palatal view of new provisional crown of the extruded tooth.

did not begin the treatment plan due to a personal matter and waited for 10 months. At that time, periodontal sounding and periapical films found that the bone height was unchanged. The overall tooth extrusion was about 3 mm and the gingival height had increased approximately 2 mm (Fig. 4B). A gingivectomy was performed to even the gingival height of both central incisors, emergence contour of #11 was adjusted accordingly. At the follow up appointment after gingival maturation, #11 provisional endocrown was removed, and the tooth was installed with a fiber post and resin core (Fig. 5). Then, tooth preparation of #11 and #21 was performed with a circumferential chamfer margin configuration. Since subgingival overcontouring of #11 was indicated for the narrower root, the margin finalization for #11 was more conservatively (Fig. 7A). Impressions were made with vinyl polysiloxane impression material, and splinted ceramic crowns (IPS e.max Press; Ivoclar Vivadent) of #11 and #21 were cemented with resin cement. The results of a 14-years of follow up demonstrated good esthetic results and periodontal health of #11 with a mild discrepancy of free gingival margin between the central incisors clinically. Root resorption at apex of #11 was noted in the radiographic examination (Fig. 7).

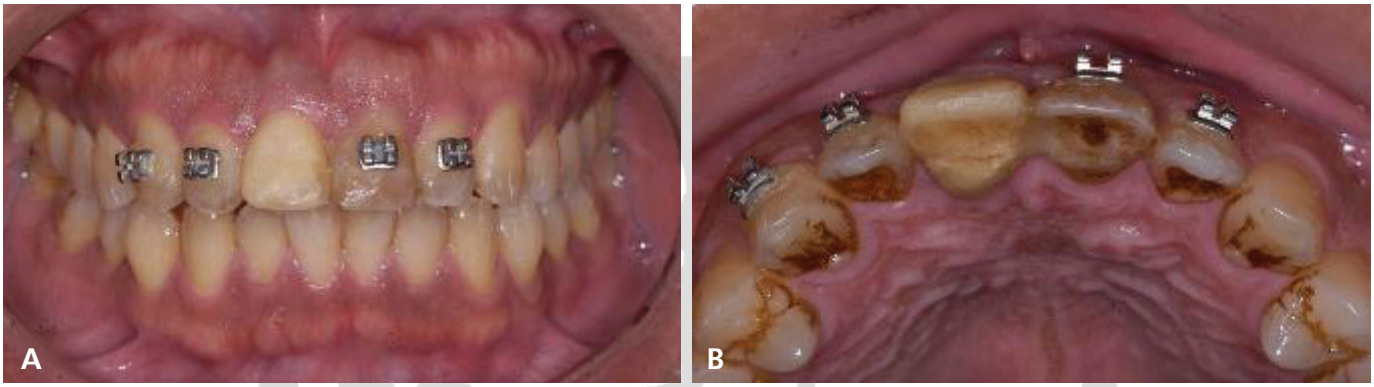

Figure 6. Stabilization of extruded tooth with resin bonding to adjacent provisional crown after orthodontic extrusion.
(a): Facial view. (b): Palatal view.

Figure 7. (a): Final preparation of central incisors.
(b): Delivery of splinted ceramic crowns at delivery.
(c): Radiograph showing apical root resorption at delivery.
(d): Front view of splinted ceramic crowns at 3 years of follow up.
(e): Front view of splinted ceramic crowns at 14 years of follow up.
(f): Radiograph showing stable bone height at 14 years of follow up.

Discussion

Fracture teeth are a common problem following accidents, and the position of the fracture line dominates the subsequent dental management and treatment plan. Orthodontic extrusion is a useful tool to relocate the fractured margin to provide a sound ferrule and biologic width while restoring teeth. In this case report, we address the importance of the preservation of labial bone plate of the traumatized central incisor. Undesirable excessive extrusion force may create an undesirable horizontal vector of force toward the labial direction and cause bone resorption (Figs. 8A & 8B). Previous studies had shown the labial bone plate of incisors is relatively thinner than the palatal bone, and usually less than 1 mm thick at marginal bone [10,13,14].

To reduce the risk of labial bone resorption, couple of methods can avoid the undesirable horizontal vector of force to erupt the tooth labially. Especially in the esthetic zone, a well-designed multiple-loop orthodontic appliance with adequate torque control is highly recommended [15-17]. The lingual orthodontic technique is another modality for forced eruption therapy that provide favorable horizontal vector of force and esthetic needs [18]. Nozawa et al.[10] demonstrated that forced eruption combined with buccal root torque could induce buccal and coronal bone augmentation around an irretrievable tooth. Further, orthodontic extrusion of a fractured root utilizing a custom-made intra-canal wire loop or hook also showed a promising result if the force is applied along the tooth axis [19,20]. However, forced eruption of the fractured root without temporization compromised the esthetics

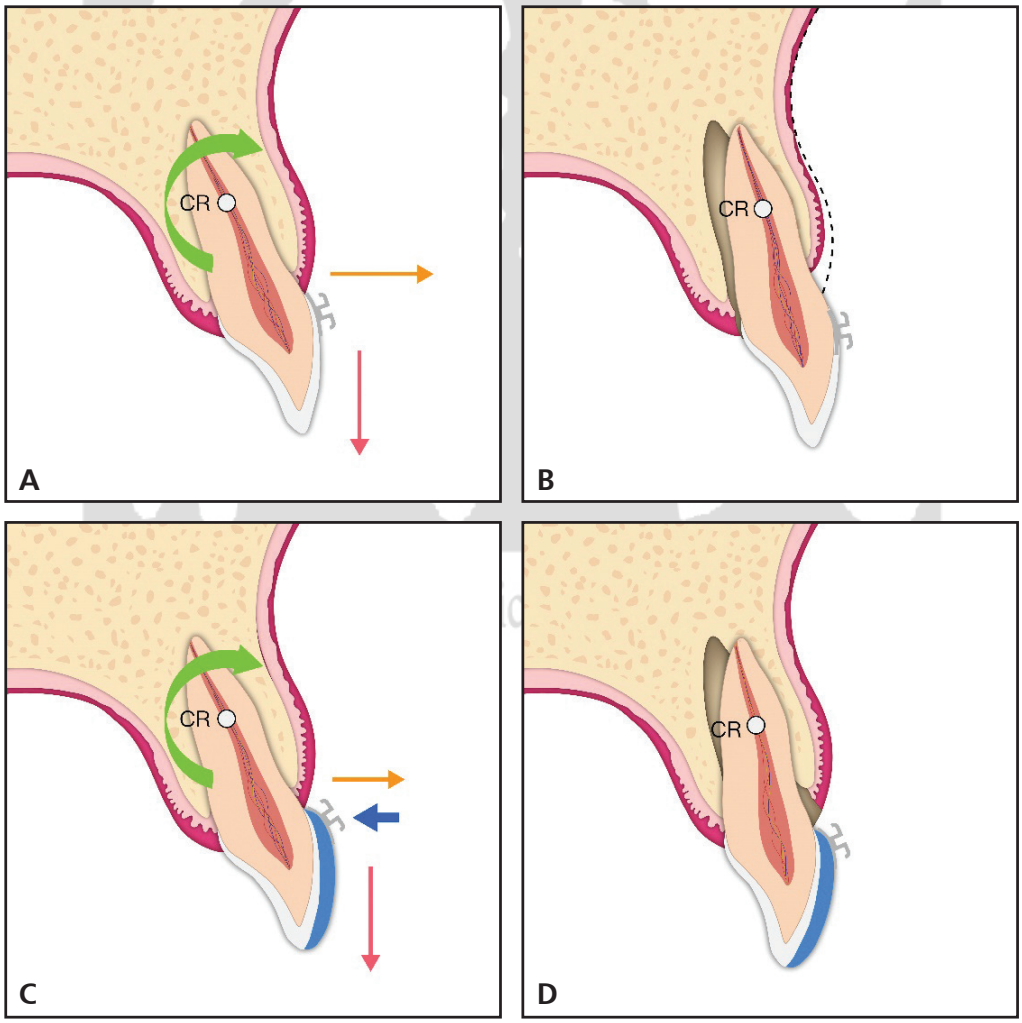

Figure 8. (a): Extrusion force is not through the center of rotation (CR), which causes clockwise rotation of the tooth.
(b): Vertical vector of orthodontic force causes tooth extrusion, while horizontal vector could cause labial bone resorption and marginal gingiva recession.
(c): Thickening the buccal wall of provisional restoration provides palatalized vector (blue arrow) during orthodontic extrusion.
(d): Increasing palatalized vector during orthodontic extrusion reduced the risk of labial bone resorption and marginal gingiva recession.

and could induce tipping of the adjacent tooth (Fig. 4D). To avoid any possible undesired pressure force applied on the fragile labial bone plate, Hochman et al.[15] showed a sophisticated example of orthodontic extrusion using a provisional restoration with intracoronal elastics to apply a force through the long axis of a tooth. Instead, this case report presented a simple way to protect the labial bone plate and provide certain function of esthetics by using a provisional Endo crown with an additive contour at the facial gingival level (Figs. 8C & 8D). The outcome of the extruded #11 showing a stable labial tissue profile was promising (Figs. 7E & 7F). However, it is noteworthy that the forward clockwise moment during orthodontic extrusion will cause the root apex to be driven in a facial direction and cause possible bone perforation. Therefore, case selection is critical when adopting this technique [13,15].

The force necessary to extrude a tooth majorly depends on the root morphology, and amount and density of bone on the tooth to be extruded. Therefore, the exact amount of force optimal for tooth extrusion could not precisely estimated. A wide range of extruding forces were suggested by previous references. The force can be as low as 15-30 g to extrude the tooth [21,22], and as high up to 80 g for the tooth with a long root and dense bone surrounding [15,23]. There is no consensus on the rate of tooth extrusion in published studies, since slow or rapid forced eruption will achieve different periodontal implications. There will be compensatory growth of bone and soft tissue if the root is extruded slowly as 1 mm per month, while the tooth can be extruded from the alveolar bone without significant bone deposition if the root is extruded rapidly as 1 mm per week [24,25]. In this case, to minimize bone downward growth after forced eruption, rapid extrusion with supracrestal fiberotomy was proposed. Further, the fiberotomy procedure was also beneficial to limit the relapse intrusion of the extruded root. However, some discrepancy between the gingival margin level of the treated tooth and the adjacent teeth was found in this case, which is in line with our projections and related references [26,27]. Because supracrestal fiberotomy is unable to completely prevent displacement of the gingival attachment, additional orthodontic therapy or surgical correction may be necessary. In this case, the discrepancy between adjacent gingival levels was corrected by a conservative gingival surgery [27,28].

Closely monitoring the periodontal response during forced eruption is mandatory. According to the fundamental rule of the biologic width, at least 3 mm of sound dental tissue above the alveolar bone crest should be extruded. At the completion of forced eruption achieving the desired amount of extrusion, the tooth must be stabilized for hard and soft tissue maturation and to prevent relapse intrusion. Since soft tissue growth may be visible during the stabilization period, the longer the stabilization period, the more likely such growth will occur. In this case, minor periodontal surgery might be necessary to remove gingival or even bony excess. In this case, the extruded #11 was splinted with #21 provisional crown to maintain stabilizing force against root intrusion for 10 months, as previous references suggested one month of stabilization for every millimeter of extrusion [25,29,30]. In order to minimize relapse, supracrestal fiberotomy immediately prior to the initiation of the stabilization period is highly recommended [31]. Using a scalpel to perform supracrestal fiberotomy is a common way, while electrosurgical fiberotomy was adopted in this case for easy bleeding control [32,33]. The procedure did not interfere with the outcome of periodontal health and orthodontic extrusion. Recently, laser fiberotomy has gained more attention in clinical and laboratory studies [34-36], and their results seem to be encouraging.

Lingualized movement of #11 during orthodontic extrusion not only minimized the risk of labial bone plate resorption or dehiscence, but also generated space for the future restoration (Fig. 8D). Therefore, tooth preparation for the extruded tooth can be kept as minimum as possible to preserve tooth structure. However, it should be noticed that the projection of the final restoration should be carefully judged at the early diagnosis and treatment for the fractured tooth. The location of fracture line decides the final crown-root ratio of the tooth, while the root form at the point of fracture dominates the emergence profile and the final esthetics. A tapered or narrow root form will produce a narrow neck on the final crown. Although crowns with an increased contour beneath gingiva can be fabricated to improve the emergence profile, there is a potential risk of gingival recession or interproximal bone loss facing overcontoured restorations. In this case, the esthetics was compromised to strive for the optimal periodontal health. An emergence profile favorable to periodontal tissue was designed for

#11 crown. The narrow emergency profile of the crown, comparing to the adjacent incisor (Fig. 7E), induced a complimentary growth of gingiva in to the emergence zone was observed at the 14 year follow-up (Fig. 7D). However, clinical and radiographic findings revealed a healthy condition of soft tissue and hard tissue. The soft tissue color and texture at the labial aspect of the extruded incisor mimicked that of the contralateral incisor, including an adequate width of keratinized gingiva, and the patient was pleased with the favorable esthetic result.

The limitations of this technique should be mentioned that the bracket on the overcontoured provisional crown may result in undesired gingival irritation and cause a loss of the normal self-cleansing morphology of the tooth, resulting in potential periodontal problems. The rapid extrusion with fiberotomy, although was an efficient way to reposition the fractured margin, the possible trade-off in root resorption should be reconsidered. Another possibility of root resorption observed in this case may have been caused by the tipping movement, which merits further exploration and study.

Conclusion

This case report presented a simple and effective technique to extrude the central incisor with a complicated crown-root fracture. With carefully case selection, the labial hard and soft tissue can be persevered, which not only benefits the crown restoration for the fractured roots but also provide a good bone housing for the future implant. Mastering this technique of orthodontic extrusion is a valuable aid to the interdisciplinary practice because they offer predictable results for prosthodontists.

Acknowledgement and disclosure

The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

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Literature Review

Types of clinical application of rotational path removable partial dentures: a literature review.

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Introduction

Rotational path of insertion has been applied in removable partial prosthesis for decades. Although the term of 'rotational path of insertion' was not yet established in 1958, Mann[1] proposed the concept of rotary path by using Hart-Dunn attachment in unilateral distal extension removable partial denture design. The system was reintroduced in nineteen seventy by many authors[2-4] and presently, the term 'rotational path of insertion'[5] was widely accepted. Missing anterior teeth and missing posterior teeth with tilted mandibular molars were the most popular situations reported. Other clinical applications were also described in the following years,[5-13] but were not received considerable attention.

A questionnaire survey described by Jacobson in 1994,[14] members of the Academy of Prosthodontics in the United States were asked to provide responses. Eighty percent of respondents believed that they fully understood the concept of rotational path of insertion and 50% of respondents used the technique in situations that required the elimination of clasps and experienced long-term favorable success rates. Possible reasons of the other half of respondents not using the technique may be due to lack of sufficient understanding of the concept, absence of documented evidence of long-term clinical success, a general lack of confidence in the efficacy of the procedure as described in the literature and difficulties in obtaining knowledgeable laboratory support.

Rotational path of insertion is a feasible treatment modality, but it is underutilized[15,16] or overlooked.[17,18] For encouraging its application, more investigation to clarify the rationale and criteria in the application of rotational path is needed. Therefore, the aim of our study is to collect previous publications that described and discussed the clinical application of rotational path of path in web wide or other resources. Types of clinical situations appropriate to apply rotational path of insertion for removable partial denture design are analyzed and the overall scope of clinical application of the technique is determined.

Material And Methods

Four electronic resources (PubMed, Medline + Journals @ Ovid, ScienceDirect and Google scholar) were used to identify the articles about rotational path of insertion from January 1, 1970

to December 31, 2020. Keyword combinations were rotational path, rotational path of insertion, rotational path removable partial denture, dual path, dual path of insertion, aesthetics, with the prefix 'AND' and 'OR'. In addition, the cited references in the identified articles were also manually assessed for searching relevant articles that were probably missed. Then, the identified articles were screened to exclude the articles not using English language, not mentioning rotational path, not discussing clinical application, original research articles, abstract, reader's round table, comment, poster, and duplicates. Finally, the eligible articles related to clinical report or clinical technical discussion were included in the study for analysis.

The full text articles were then reviewed to identify the various types of rotational path removable partial denture applied in different clinical situations. The characteristics of each type of clinical application such as Category classification, insertion direction and sequence, and Kennedy classification were determined and recorded. The screening and reviewing procedures were performed by two reviewers (L.F.C. and L.Y.H.) independently and any disagreement was resolved by discussion with a third reviewer (L.K.C.) if required.

Results

Our search identified 106 articles including 95 from journal publications and 11 from textbooks from January 1, 1970 to December 31, 2020 . After screening, 48 articles were excluded and 58 articles related to clinical report or clinical technical discussion were finally included in the study for analysis. The study flow chart was illustrated in Figure 1. Nine types of clinical application of rotational path of insertion (RP1-RP9) were determined. RP5 had three different designs for different purposes, and therefore was denoted as RP5a[19,20], RP5b[6,8] and RP5c[10,21]. The number and percentage of articles related to each application type was shown in Table 1. RP1 to RP6 were applied in the tooth bounded situations and RP7 to RP9 were applied in distal extension situations.

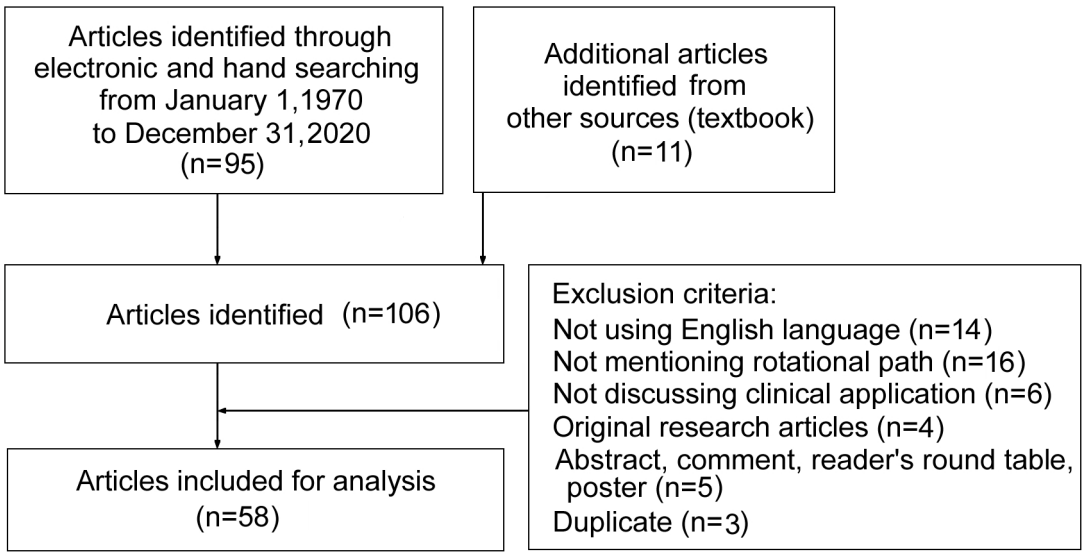

Figure 1. Study flow chart.

Table 1. The number and percentage of articles related to each application type.

Clinical application type	Number	Percentage [a]
Missing anterior teeth (RP1)	44	76%
Bilateral missing posterior teeth with tilted mandibular molars (RP2)	18	31%
Bilateral missing posterior teeth with aesthetic demands (RP3)	17	29%
Unilateral tooth bounded space with tilted abutment (RP4)	1	2%
Unilateral tooth bounded space with missing anterior and/or posterior teeth (RP5)	12	21%
Flaring anterior abutment, tooth bounded (RP6)	3	5%
Flaring anterior abutment, distal extension (RP7)	2	3%
Kennedy Class II without modification or space restored with fixed prosthesis (RP8)	3	5%
Kennedy Class II with modification, with tilted molar (RP9)	2	3%

[a] percentage=number of articles related to the type/total number of articles included (n=58)

The most popular clinical application type was missing anterior teeth (RP1) that was discussed in 44 articles of the all 58 records. The second and the third were bilateral missing posterior teeth with tilted mandibular molars (RP2) and bilateral missing posterior teeth with aesthetic demands (RP3) being 18 and 17 articles, respectively. Unilateral tooth bounded space with tilted abutment (RP4) had only one article published in the dental literature and flaring anterior abutment, tooth bounded (RP6) was discussed by the same author in his consecutive editions of the textbook. There was no invention in clinical application of rotational path of insertion published in the dental literature after 2008. The main contents of the articles reviewed were mainly design description, design concept, case selection, indication, contraindication, technical, and laboratory considerations for general or special type of rotational path removable partial dentures. Case reports were relatively uncommon. There were only twenty case reports (35%) out of all 58 reports, and fifteen of them described missing anterior teeth cases.

The result of analysis showed that each type of clinical application of rotational path of insertion possesses their unique characteristics including Category classification, insertion sequence, Kennedy classification and main purposes (Table 2).

Discussion

Rotational path of insertion can be classified by two methods. The first one is Category classification suggested by Jacobson[5,22] which is classified according to the position of the rotation center. Category I denture has its rotation center at the end of a long occlusal rest (Fig 2) and Category II has its rotation center at the most gingival extension of minor connector of rigid retentive components (Fig 3). The second one suggested by Krol[6] is a type of rotational path which is classified according to the sequence of insertion. There are three insertion types: anterior-posterior (A-P) type (Fig 3), posterior-anterior (P-A) type (Fig 2) and lateral (right to left or left to right) type (Fig

Table 2. Characteristics of each type of rotational path applications.

Application type	Category	Insertion sequence	Kennedy classification	Main purposes of design
RP1	II	A-P	Class III or IV	Aesthetics
RP2	I	P-A	Class III	Engage proximal undercuts
RP3	I	A-P	Class III	Aesthetics
RP4	I	P-A	Class III	Engage proximal undercut, unilateral denture
RP5a	II	Lateral or diagonal	Class III or IV	Aesthetics
RP5b	I	Lateral or diagonal	Class III or IV	Aesthetics
RP5c	I	Lateral	Class III or IV	Avoid breaking occlusal integrity
RP6	I	A-P	Class III	Aesthetics, cervical placement of labial clasp
RP7	II	Lateral or A-P diagonal	Class II	Aesthetics, cervical placement of labial clasp
RP8	I	Lateral	Class II	Avoid breaking occlusal integrity
RP9	I	P-A diagonal	Class II with modification	Engage proximal undercut

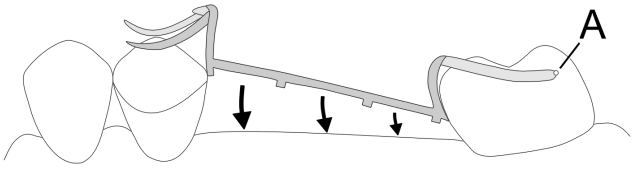

Figure 2. Schematic drawing of bilateral missing posterior teeth with tilted mandibular molars situation (RP2). It is a Category I, posterior-anterior insertion design with its rotation center (A) at the end of a long occlusal rest.

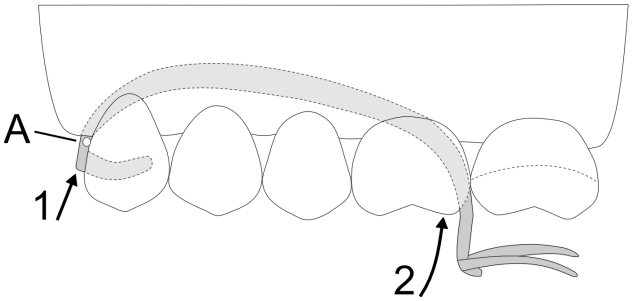

Figure 3. Schematic drawing of missing anterior teeth situation (RP1). It is a Category II anterior-posterior insertion design with its rotation center (A) at the most gingival extension of minor connector of rigid retentive components.

4). Category classification is related to position of rotation center influencing to the related undercut, retention, and the amount of block-out which will be changed from the conventional to the rotational path design; therefore, the changes should be considered by dentists and technicians. The type classification is related to the insertion sequence which gives the sense to the patient or technician how to insert the denture correctly. A diagonal rotation was mentioned by Ancowitz[23] to describe the insertion direction of the rotational path in some situations. Therefore, in our study, a diagonal type (Fig 5) is added into this classification (anterior-right to posterior-left; anterior-left to posterior-right; posterior-left to anterior-right or posterior-right to anterior-left) to provide more precise descriptions of the direction and sequence of rotational path of insertion.

There are nine types of clinical situations appropriate to apply rotational path of insertion in removable partial denture design. Each type of application possesses their unique characteristics and special designs to accomplish their purposes. Each type of clinical application is briefly described as follows.

Missing anterior teeth (RP1, Fig 3 and 6)

Missing anterior teeth is the most popular topic reported in rotational path removable partial dentures. It may be related to its effective improvement in aesthetics by removing unsightly clasp on the anterior abutments and maintaining sufficient retention. Many authors[3,4,7,9,19,22,24-30] discussed the limitation of application including the number of missing teeth, ridge form and distal extension case. It is not suitable to apply in situations with less than three missing teeth[3,4,24] because part of metal of minor connector may be shown out.[25] Sometimes, a smaller or less obvious metal finger can be substituted.[25] A large residual ridge extending anterior to the abutment teeth and rotation axis may prevent the rigid retainers reaching the area of rotation and cause laboratory and clinical difficulties.[26] Rotational path of insertion is generally not advised to apply in distal extension situations [7,9,27] because the rigid retainers will torque the abutments during rotational movements in function.[27] On the other hand, some authors agreed the application on the condition that judicious abutment selection,[22,28] firm residual ridge,[9] functional impression,[22,28] stress-breaker design,[19,22] regular close follow up and relining,[22,28] spring clasp (Twin-Flex clasp)[25,29] or modified circumferential clasp (snubber clasp)[30] were considered.

Bilateral missing posterior teeth with tilted mandibular molars (RP2, Fig 2 and 7)

It is the second popular topic in the rotational path removable partial dentures reported in the literature. The rationale and concept of this application type were fully discussed[5-8,19,22] but a complete case report has not been published. Tilted mandibular molars having undercut at mesial or mesio-lingual area, where removable partial denture is difficult to approach by conventional clasping.[3,5,6,19,20,31,32] In this rotational path design, conventional clasps on the molars are replaced by the rigid retainers of the first segment of rotational path removable partial denture, which lock into the mesial undercuts[17] and resolve the clasping problem.[8] However, patient selection should be made carefully in this application. The conditions such as shape of arch,[7,8,19,20] length of edentulous space,[7] multiple edentulous space,[8,19,20,28,33] vertical position of anterior and posterior abutment,[7] lingually tilted teeth,[8,19,20,28] projections of soft tissue and bone[7] excluding to use the rotational path were discussed. If indicated to utilize, precise laboratory works are mandatory to accomplish successful prosthesis. Special block-out procedures over some areas such as distal surfaces of the anterior abutments should be performed.[5] Some authors[5-8,17,19,20,22,24,28,33] suggested to use calipers or dividers but a specially designed block-out instrument[34] provides more precise result.

Bilateral missing posterior teeth with aesthetic demands (RP3, Fig 8)

The design concept of this application is like RP2 but with a reverse insertion sequence. It is usually applied in the maxillary arch for aesthetic reasons, as this design eliminates buccal and lingual clasps of anterior abutments.[8] In RP2 design, rotation axis is on the distal end of long occlusal rest of tilted molars and in this design, the rotation axis is changed to anterior end of occlusal rest of the canine or premolar. Canine or premolar is usually in an up-righting position, so their distal undercut is relatively less. Therefore, the distal contours of the anterior abutment teeth permitting the use of rigid retainer is crucial to the success of this design.[8,17,32] Placement of cast restoration[5,14,35,36]or bonded composite resin restoration[36,37] may be required to provide proper proximal tooth contours.

Unilateral tooth bounded space with tilted

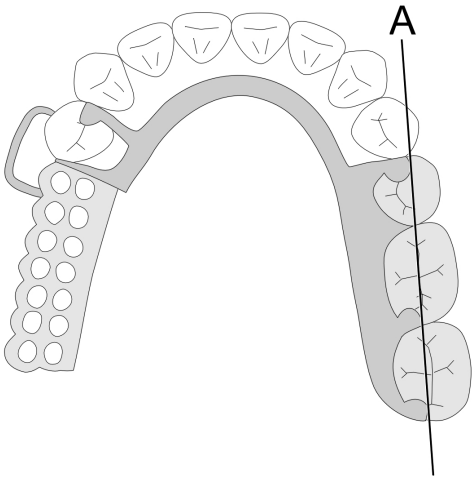

Figure 4. Schematic drawing of Kennedy Class II without modification or space restored with fixed prosthesis situation (RP8). It is a Category I, lateral type design with its insertion sequence from right to left. A, rotation axis.

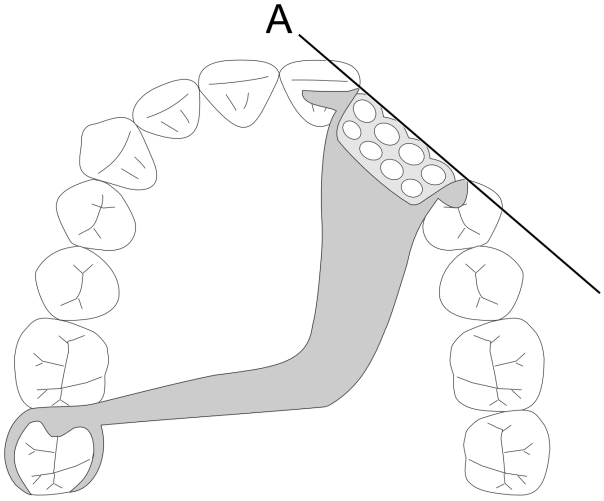

Figure 5. Schematic drawing of unilateral tooth bounded space with missing anterior and/or posterior teeth situation (RP5a). It is a Category II, diagonal type design with its rotation axis (A) on edentulous side and its insertion sequence from anterior-left to posterior-right.

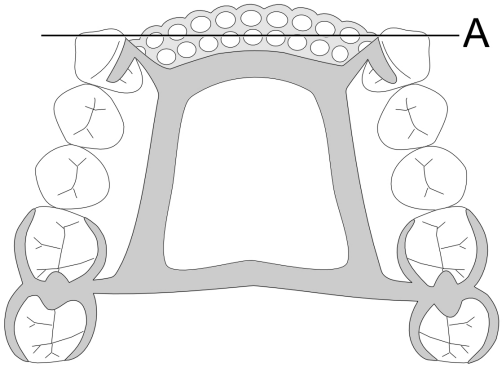

Figure 6. Schematic drawing of missing anterior teeth situation (RP1). A, rotation axis.

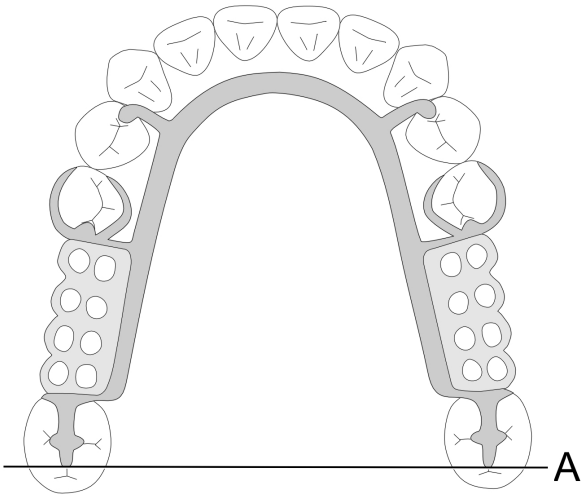

Figure 7. Schematic drawing of bilateral missing posterior teeth with tilted mandibular molars situation (RP2). A, rotation axis.

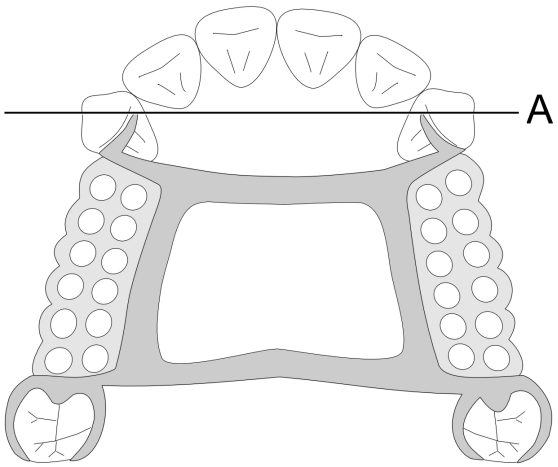

Figure 8. Schematic drawing of bilateral missing posterior teeth with aesthetic demands situation (RP3). A, rotation axis.

abutment (RP4, Fig 9)

This application type had only one report in 1997.[12] Ordinarily, a fixed prosthesis is the first choice to replace a single edentulous space. However, there remains a group of patients that, for medical, psychologic, and financial reasons, are poor candidates for fixed prosthodontics.[16] Bilateral removable partial denture for a small missing space is often rejected by patients, because the benefit to function does not balance the suffering to the foreign body sensation. A unilateral RPD design is often rejected by some dentists due to risk of accidental swallowing[38,39] and its poor retention and stability.[40] This unilateral rotational path design may overcome the problems of retention and stability and to reduce the chance of inhalation or swallowing the prosthesis. This unilateral design is modified from the original bilateral rotational path design (RP2). A bilateral design having two rotation centers on the two distal abutments on both sides. Therefore, the direction of the rotation axis is relatively fixed and can be adjusted in a limited range. On the other hand, a unilateral design has only one fixed rotation center, the other one is virtual in space and the rotation axis can be adjusted to a favorable direction to provide reasonable block-out, retention, and guiding plane.[12] So, the retention and stability can be controlled in this small prosthesis. The most suitable clinical condition for this rotational path application is missing mandibular first and second molars with mesially tilted third molar.

Unilateral tooth bounded space with missing anterior and/or posterior teeth (RP5)

This clinical situation has three design methods. The first method (RP5a, Fig 5) uses Category II design similar to RP1, but with lateral or diagonal insertion direction and sequence. [19,20,23] Anterior clasp is eliminated and replaced by rigid retainer and however, that of posterior abutment can be preserved or omitted.[14,41] One or two conventional direct retainers on contralateral side (dentate side) are the main retentive components of the whole denture, but for aesthetic reason, it is always placed on molar area,[19,20,23] so a diagonal insertion pattern is formed.[23]

The second method (RP5b, Fig 10) uses Category I rotational path described by Krol.[6,8] In his design, the rotation axis run between two buccal borders of long occlusal rests which are located at the middle of bucco-lingual dimension of occlusal surfaces of the anterior and posterior abutments of the edentulous ridge. Buccal clasps of anterior and posterior abutments are eliminated. Lingual or palatal undercuts or embrasures are engaged by lingual or palatal plates while denture is at its final position. The components buccal to the rotation axis such as the buccal flange and denture base of the edentulous area should be eliminated or relieved to avoid interference to the rotational path during insertion. Moreover, the design for the retentive clasp on dentate side is generally embrasure rest and clasp, which is unaesthetic if placing forward to premolar area, and always breaks occlusal integrity and easily broken.[32,42] A Category II design

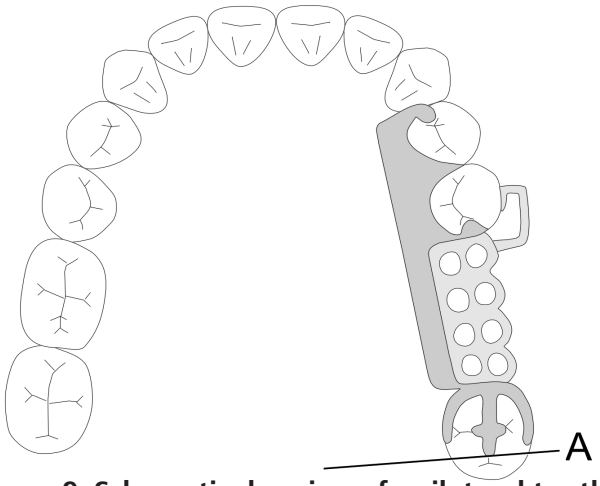

Figure 9. Schematic drawing of unilateral tooth bounded space with tilted abutment situation (RP4). A, rotation axis.

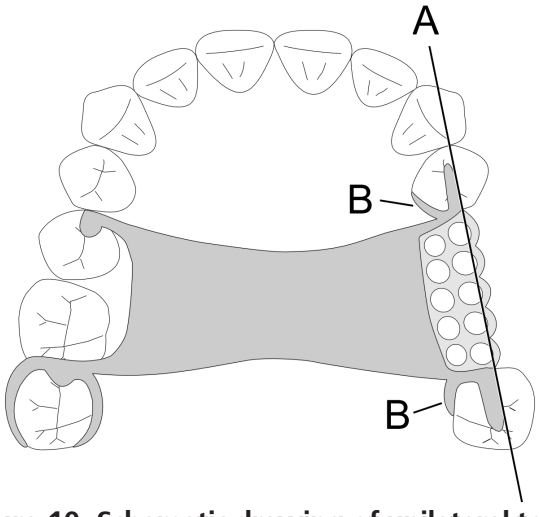

Figure 10. Schematic drawing of unilateral tooth bounded space with missing anterior and/or posterior teeth situation (RP5b). It is a Category I design with its rotation axis (A) on edentulous side. B, rigid retentive components.

(RP5a) seems to be better for this situation if buccal undercut of abutments of edentulous side are sufficient.

The third method (RP5c, Fig 11) described by Ring[10] and Baharav[21] is a Category I design with its rotation axis on the dentate side. It is like the design of Kennedy Class II without modification or space restored with fixed prosthesis (RP8) being discussed later. The purpose of this design is to solve the problem of tight occlusion on the dentate side and to avoid breaking occlusal integrity. By using a rotational path, the lingual or palatal plate, the rigid retentive component can be engaged to the lingual or palatal surface, or embrasure area. On the edentulous side, anterior clasp is eliminated due to aesthetic reason, so main retention is provided by a posterior retentive clasp.

Flaring anterior abutment, tooth bounded (RP6, Fig 12)

This application type was only reported in the textbook edited by Krol in his consecutive editions.[6,19,20,31] He described the curved path of insertion[31] in his second edition of the textbook in 1976 that it may be used when anterior teeth are flared labially and aesthetic clasping would be difficult. Curved path permits placement of clasps in the cervical area of the teeth. In the third and fourth editions,[6,19] he used the term of rotational path or dual path instead of curved path of insertion. And in the fifth edition, he described more to the design of the anterior clasp that a bar clasp is usually most effective.[20] It is an innovative idea that a conventional flexible direct retainer rather than a rigid retainer can be used in the rotational path design. However, there was no other publication describing this concept by other authors.

Flaring anterior abutment, distal extension (RP7, Fig 13)

Donovan[13] described a case report to use the rotational path concept in a Kennedy Class II patient. The design of this rotational path denture is Category II with an anterior to posterior diagonal insertion direction. The purpose of the application is for aesthetics because the labial clasp of the anterior abutment can be eliminated. The rigid retainer (a distal proximal plate) engaging to distal undercut of distal surface provides retention. Recently, a modification design was reported by Syu.[43] A flexible retentive clasp rather than a rigid retainer was designed on the anterior abutment and placed more cervically using the concept by Krol.[19,20,31] In the Kennedy Class II distal extension situation, denture stability is more important than aesthetics. The denture base on the distal extension edentulous ridge tends to move distally, therefore, the labial clasp on the distal abutment tooth is not only for retention, but for stability of the denture.

Kennedy Class II without modification or space restored with fixed prosthesis (RP8, Fig 4)

This application type is the earliest application reported in dental literature. It was first reported by Humphreys[17] in 1935, and has evolved over the years. Finally, the Hart-Dunn attachment was

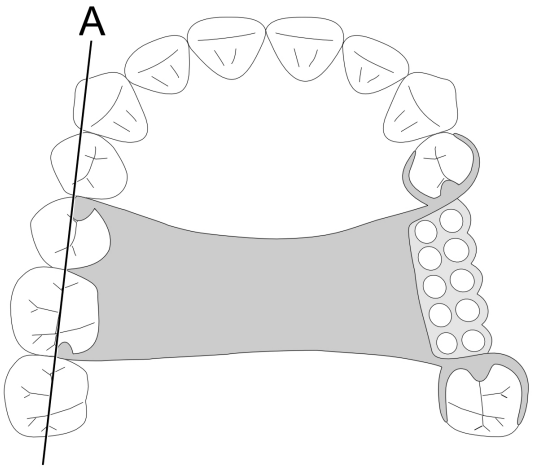

Figure 11. Schematic drawing of unilateral tooth bounded space with missing anterior and/or posterior teeth situation (RP5c). It is a Category I design with its rotation axis (A) on the dentate side.

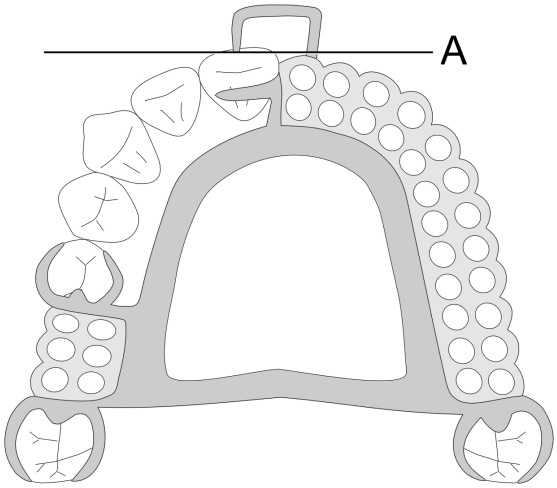

Figure 12. Schematic drawing of flaring anterior abutment, tooth bounded situation (RP6). A, rotation axis.

described by Mann[1] used embrasure clasping on the dentate side for the retention of unilateral distal extension partial dentures and proposed the concept of rotatory path. Although Garver[2] modified this design further in 1978, its use was limited, because it was specified for a Kennedy Class II situation with a fixed partial denture on the contralateral side. After rationale and principle of rotational path were developed and discussed in the following years,[3,5] specially designed fixed partial dentures on the contralateral side are not required, and the versatility of the application is increased. Some authors[10,21] used lingual or palatal minor connector to engage lingual or palatal undercut or sub-pontic undercut over the fixed prosthesis which restored the modification space of Kennedy Class II situation (RP8), and Kennedy Class III or IV situations (RP5c). When applying in Kennedy Class II situations, force control on the contralateral side is mandatory. Usually, the area of engagement is restricted and should be adjusted to avoid harmful force applied to the abutment during function on distal extension side. On the contrary, force control is not the major consideration in RP5 tooth bounded situations.

Kennedy Class II with modification, with tilted molar (RP9, Fig 14)

This application was described by Asher[11] in 1992. It is classified as Category I, with a diagonal insertion direction from the posterior of one side to the anterior of the other side. Biomechanical principles should be considered to avoid deleterious force on the mesial surface (usually mesio-lingual surface) of the posterior molar abutment on the tooth-bounded ridge by the rigid retentive retainer in application of rotational path to construct a removable partial denture for Kennedy Class II distal extension situation. This design is also applied in Kennedy Class II without modification. In a case report by Syu,[43] a rigid retainer was designed to engage mesio-lingual undercut of tilted molar on the dentate side.

In our study, nine application types were determined and may be applied in various clinical situations when indicated. According to different clinical situations, some modifications to the standard design were used for fulfilling different purposes.[12,25,43] The number of reports related to each type of clinical application is not positively correlated to the importance of that application type but represents that its clinical result is attractive and more easily shown in the literature. Missing anterior teeth is a representative example in the rotational path of insertion. In this application type, it is an effective improvement in aesthetics by relatively simple design. Therefore, it is so popular that discussion about RP1 was found in 76% of all included articles in our study. The frequency of the application of rotational path in removable partial denture design may be different in various districts or countries according to the patient's demographics, psychology, systemic and oral health,[44,45] medical supply ability, the ability, experience and preference of dental practitioner and technician.

The purposes of use of the rotational path of insertion are different in various types of application. Generally, in designing a removable partial denture, if the condition can be managed by conventional method, a rotational path is not considered. It is because the conventional method is more straight forward thinking and more easily communicates

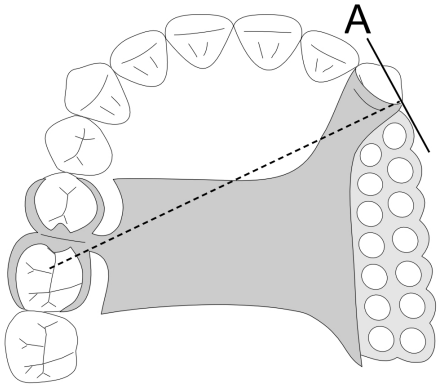

Figure 13. Schematic drawing of flaring anterior abutment, distal extension situation (RP7). A, rotation axis.

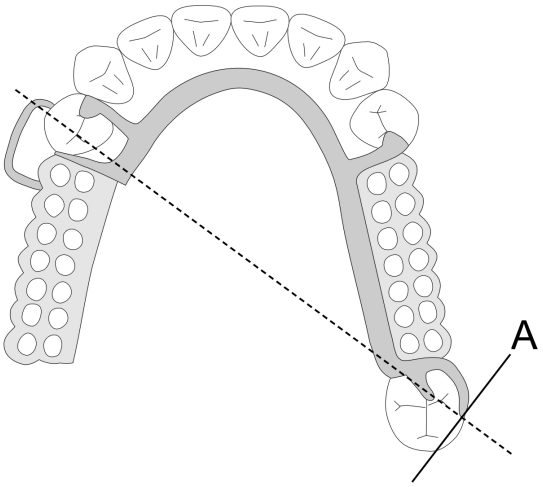

Figure 14. Schematic drawing of Kennedy Class II with modification, with tilted molar situation (RP9). A, rotation axis.

with the technicians and the result and the effect are more predictable. Therefore, the rotational path is only a supplemental tool to assist or to solve some problems encountered in conventional denture design. In the literature review, improving aesthetics and engagement of a difficult approaching undercut are the major reasons to apply rotational path of insertion.

Generally, if the rotational path is used in anterior portion, it is for aesthetic reason so that unsightly clasp may be eliminated. If it is used in the posterior area, aesthetic is less important, so it is for the engagement of difficult approaching undercuts. At last, if it is used in distal extension situations, it may provide aesthetics or retention. However, biomechanical principle should be considered in the design to avoid harmful force on the abutments engaged by rigid retentive components.

In our study, it was concluded that rotational path of insertion is a feasible technique and it is worth encouraging dental practitioners to utilize this technique in appropriate clinical situations. However, the clinical application types determined in our study were based on relative weak evidence (clinical descriptions and case reports). In the future, further studies are needed to evaluate the clinical performance and long-term outcome of this technique. In addition, the consideration for rotational path of insertion in computer-aided design (CAD) software should be evoked.

Conclusions

In the literature review, it was known that there were nine application types that rotational path of insertion can be applied in various situations including tooth bounded or distal extension, anterior or posterior, unilateral or bilateral conditions. In removable partial denture design, conventional path of insertion is in the first place to be considered. However, there are limitations in conventional design and the rotational path of insertion as a supplemental tool is to assist or to solve some problems in denture design. Biomechanical principles are the common factors considered in both the conventional and rotational path of insertion. Each type of application of rotational path has different clinical consideration and purposes to be accomplished, and so possesses different design and characteristics. Appropriate design by dental practitioners and precise laboratory works by well-trained technicians are the foundation of successful prosthesis.

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Introduction for authors

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All works related to basic or clinical prosthodontics, temporomandibular joints or masticatory function, dental implants, and technical science of dental prosthodontics are the objects of publication. There are five types of accepted manuscripts, please indicate the type of manuscript.

- Review article
- Original article
- Technical report
- Case report
- Letters to the Editor

General Format guide

- Articles must not have been published or will be accepted for publication in other journals.
- Please write your text in good English (American or British usage is accepted, but not a mixture of these) , and the content of the article is typed in double spacing, with font size 12 and above, with at least 2.5 cm margin on each side, and without any formatting.
- The total number of pages of the full text (including abstract, figures, tables, and references) is limited to eight pages, and can be extended to twelve pages if necessary.
- Please use electronic documents to submit manuscripts. IBM-Microsoft Word is recommended as the word processing program. The program used, the title of the manuscript, and the name of the first author must be marked. The electronic file should be emailed to: prosthor@ms48.hinet.net.
- Please also include a short letter to the Editor-in-Chief of the Journal stating that you would like to contribute to the Journal and stating that all authors have read and signed the consent form. If the research involves the use of human subjects, the manuscript must be accompanied by the consent of the appropriate institutional review board or ethics committee.

Review Articles Format Guide

These should aim to provide the reader with a balanced overview of an important and topical issue in prosthodontic field. They should cover aspects of a topic in which scientific consensus exists as well as aspects that remain controversial and are the subject of ongoing scientific research. All articles or data sources should be selected systematically for inclusion in the review and critically evaluated.

- Abstract: required, up to 400 words, unstructured (i.e., no subheadings)
- Keywords: up to 10
- Word limit: 3500 words
- References: up to 100
- Tables/Figures: 1 maximum

Original Articles Format Guide

Section headings should be: Abstract, Introduction, Materials and methods, Results, Discussion, Conclusion Conflicts of Interest Statement, Acknowledgments (if any), and References.

(1) ***The Introduction*** should provide a brief background to the subject of the paper, explain the importance of the study, and state a precise study question or purpose.

(2) ***The Materials and methods*** section should describe the study design and methods (including the study setting and dates, patients/participants with inclusion and exclusion criteria, patient samples or animal specimens used, the essential features of any interventions, the main outcome measures, the laboratory methods followed, or data sources and how these were selected for the study), and state the statistical procedures employed in the research.

(3) ***The Results*** section should comprise the study results presented in a logical sequence, supplemented by tables and/or figures. Take care that the text does not repeat data that are presented in tables and/or figures. Only emphasize and summarize the essential features of the main outcome measures, and the main results.

(4) ***The Discussion*** section should be used to emphasize the new and important aspects of the study, placing the results in context with published literature, the implications of the findings.

(5) The conclusion that follows from the study results.

- Abstract: required, up to 400 words
- Keywords: up to 10
- Word limit: 3000 words
- References: up to 40

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These are short discussions of a case / case series/ technique report with unique features not previously described that make an important teaching point or scientific observation. They may describe novel techniques or use of equipment, or new information on diseases of importance. Section headings should be: Abstract, Introduction, Case Report, Discussion, Conflicts of Interest Statement (if any), Acknowledgments (if any), and References.

Case reports should have no more than 6 authors. The maximum length is 2000 words, and the number of references should not exceed 10.

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Brief letters of constructive comments in response to previously published JDS articles are welcome. Ensure that the corresponding author's mailing and e-mail addresses are included. Letters are edited, sometimes extensively, to sharpen their focus. They may be sent for peer review at the discretion of JDS Editors. Letters are selected based on clarity, significance, and space.

- Author: up to 3
- Word limit: 250 words
- Tables/Figures: 1 maximum

Manuscript Preparation

Text should be typed double-spaced on one side of white A4 (297 × 210 mm) paper, with outer margins of 2.5 cm. A manuscript should include a title page, abstract, text, references, conflicts of interest statement (if any), acknowledgments (if any), and figures and tables as appropriate. Each section of the manuscript should begin on a new page. Pages should be numbered consecutively, beginning with the title page.

The detailed specifications of the manuscript content are as follows:

➢ ***Title page***

The title page should contain the following information (in order, from the top to bottom of the page): article category article title names (spelled out in full) of all authors*, and the institutions with which they are affiliated†; indicate all affiliations with a superscripted lowercase letter after the author's name and in front of the matching affiliation corresponding author details (name, e-mail, mailing address, telephone and fax numbers). A running title must be within 40 characters. Please provide the detailed information of the corresponding author (name and address in English, telephone and fax numbers, email address).

➢ ***Abstract and keywords***

An abstract (no longer than 400 words) and relevant keywords (limited to 5) are required.

(1) Abstracts for **Review Articles, Case Reports and Technique report** should be *unstructured (in one single paragraph with no section headings)*, and include information on the background/purpose of the report, methods, results (or case report), and conclusions.

(2) Abstracts for **Original Articles** should be structured into the following sections. **Aims:** briefly explain the importance of the study topic and state a precise study question or purpose. **Materials and Methods:** briefly introduce the methods used to perform the study; include information on the study design, setting, subjects, interventions, outcome measures and analyses as appropriate. **Results:** briefly present the significant results, with data and statistical details such as p values where appropriate; be sure that information in the abstract matches that in the main text. **Conclusion:** state the meaning of your findings, being careful to address the study question directly and to confine your conclusions to aspects covered in the abstract; give equal emphasis to positive and negative findings.

(3) Keywords should be taken from the Medical Subject Headings (MeSH) list of Index Medicus (http://www.nlm.nih.gov/mesh/meshhome.html).

➢ ***Main Text***

(1) **Review article:** Review articles should be unstructured (no fixed format).

(2) **Original article:** The text for original articles should be organized into the following sections: introduction, materials and methods, results, discussion, and conclusion.

- Introduction: Briefly explain the origin of the research.
- Materials and methods: Describe the research design, objects, and procedures.
- Results: The results are expressed in words, tables or illustrations.
- Discussion: Emphasize important results and arguments, and compare with previous studies.
- Conclusion: The conclusion should be concise and clear.
- Conflicts of interest statement
- Acknowledgments (if any)
- References

(3) **Technical report**

Sections for technical reports are Introduction, Methods, and Discussion, Conflicts of interest statement (if any), Acknowledgments (if any), and References. Each section should begin on a new page.

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Sections for case reports are Introduction, Case description, and Discussion, Conflicts of interest statement (if any), Acknowledgments (if any), and References. Each section should begin on a new page.

(5) **Abbreviations**

Where a term/definition will be continually referred to, it must be written in full when it first appears in the text, followed by the subsequent abbreviation in parentheses. Thereafter, the abbreviation may be used. An abbreviation should not be first defined in any section heading; if an abbreviation has previously been defined in the text, then the abbreviation may be used in a subsequent section heading. Restrict the number of abbreviations to those that are absolutely necessary and ensure consistency of abbreviations throughout the article. Ensure that an abbreviation so defined does actually appear later in the text (excluding in figures/tables), otherwise, it should be deleted.

(6) **Numbers**

Numbers that begin a sentence or those that are less than 10 should be spelled out using letters. Centuries and decades should be spelled out, e.g., the Eighties or nineteenth century. Laboratory parameters, time, temperature, length, area, mass, and volume should be expressed using digits.

(7) **Units**

Système International (SI) units must be used, with the exception of blood pressure values which are to be reported in mmHg. Please use the metric system for the expression of length, area, mass, and volume. Temperatures are to be given in degrees Celsius.

(8) **Names of drugs, devices and other products**

Use the Recommended International Nonproprietary Name (rINN) for medicinal substances, unless the specific trade name of a drug is directly relevant to the discussion. Generic drug names should appear in lowercase letters in the text. If a specific proprietary drug needs to be identified, the brand name may appear only once in the manuscript in parentheses following the generic name the first time the drug is mentioned in the text.

For devices and other products, the specific brand or trade name, the manufacturer and their location (city, state, country) should be provided the first time the device or product is mentioned in the text, for example, “”¡KSPSS version 11 was used (SPSS Inc., Chicago, IL, USA)””. Thereafter, the generic term (if appropriate) should be used.

➢ ***References***

References should be limited to those cited in the text and listed in numerical order (superscript). Please refer to Cumulated Index Medicus for the writing format. References should include, in order, all authors’ names, article title, journal name, year, volume and inclusive page numbers.

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References should include, in order, authors’ surnames and initials, article title, abbreviated journal name, year, volume and inclusive page numbers. The surnames and initials of all the authors up to 6 should be included, but when authors number 7 or more, list the first 3 authors only followed by “et al”.

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