EVALUATION OF LONG-TERM EFFICACY OF FORCED ERUPTED TEETH FOR RESTORATIVE PURPOSES – A CLINICAL RETROSPECTIVE STUDY

BY

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A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF PENNSYLANIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE UNIVERSITY OF PENNSYLANIA 2021

University of Pennsylvania Dental Medicine

EVALUATION OF LONG-TERM EFFICACY OF FORCED ERUPTED TEETH FOR RESTORATIVE PURPOSES – A CLINICAL RETROSPECTIVE STUDY

THESIS

Presented to the Faculty of Penn Dental Medicine in Fulfillment of the Requirements for the Degree of Master of Science in Oral Biology

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To my loving parents who, without their support and prayers I wouldn’t be where I am today.

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List of Abbreviations

1. *SRP – scaling and root planing.*
2. *PD – Probing depth.*
3. *BOP – Bleeding on probing.*
4. *REC – recession.*
5. *KT- Keratinized tissue.*
6. *CAL – Clinical attachment level.*
7. *SUP – suppuration.*
8. *CI – confidence interval.*
9. *SE – Standard error.*
10. *EMR – Electronic medical records.*
11. *FE – Forced eruption.*
12. *Rt-Retention.*
13. *PDM – Penn Dental Medicine.*
14. *PHI-Protected health information*.
15. *ASA- American Society of Anesthesiologists*

Abstract

Background: Prosthetically compromised teeth (e.g., insufficient ferrule) and hopeless teeth (e.g., due to extensive caries or endodontic failure) present a number of restorative treatment challenges. In cases with pristine adjacent teeth and intact periodontium or a hopeless tooth that demands vertical alveolar bone augmentation, forced eruption is a conservative treatment approach. Current evidence in the literature is lacking in regard to the long-term (> 1 year) prognosis of forced erupted teeth.

Aim: To evaluate the long-term (>1 year) stability of teeth that have been orthodontically treated with forced eruption for restorative purposes.

Materials and Methods: This study is an investigator-initiated, retrospective. clinical study. Inclusion criteria: Patients receiving orthodontic extrusion in PDM between the years of 2012 to 2020, all ages, systemically healthy, medical records consist of radiographs, clinical pictures prior to and after extrusion. Exclusion Criteria: patients with active periodontal disease or patients with acute endodontic infection. Radiographic measurements were done before and after treatment to measure 1) crown margin to the crest of the alveolar bone, 2) root length. Clinical parameters measured included 1) activation time, 2) retention time, 3) total treatment time, 4) additional treatment required to restore the teeth, 5) pre/post-surgical complication, and 6) associations between clinician training and complication rate.

Results: Twenty-five (25) participants with a total of thirty-six (36) orthodontically extruded teeth were included in the study. Mean activation time was 5.11 weeks. Mean retention before prosthetics and tooth extraction was 5.11 weeks and 12.3 weeks, respectively. The overall treatment period ranged from 3-16 months with a mean of 7.05 months. 96.0% survival rate of force erupted teeth and 4.0% failure rate due to non-restorable caries. When more than 1.0 mm

extrusion was completed, there was a statistically higher chance that the tooth required additional surgeries ($p < 0.05$). Complications during treatment was higher in clinicians who did not have orthodontic training (43.0%) when compared to clinicians with orthodontic training (10.0%).

Conclusion: Forced eruption for prosthetic treatment and implant site development is a viable and successful treatment option in the long-term.

Introduction

From ancient times, crowded, irregular and projecting teeth have been an issue for some people in society. Efforts in trying to correct those abnormalities traces back to at least 1000 BC.[1] Jacobson and Alex (1987) defined malocclusion as irregularity concerning teeth alignment and/or their relationship during dental occlusion beyond the range of what is accepted as normal.[2] Malocclusion today affects more than half of the entire world population.[3] Orthodontic therapy became a major part of everyday dentistry in recent years. It was observed that tooth movement occurs if there is prolonged light pressure applied to it causing selective bone resorption and remodeling around the tooth.[4]

In the realm of orthodontics, tooth movement is what constitutes the majority of treatment. Tooth movement is primarily a periodontal ligament (PDL) phenomenon. The PDL is a dense collagenous supporting structure that surrounds the roots and separates it from the alveolar bone of the socket. The average width of the PDL is 0.3-0.5 mm.[5] When the tooth moves through the bone via orthodontic movement, it carries its attachment apparatus with it (cementum, PDL, bone).[6] Ideal orthodontic treatment achieves maximum tooth movement without damaging periodontal tissues. The amount of force needed for tooth movement should be high enough to stimulate cellular activity without cutting off the blood supply to the periodontal ligaments.[4]

A variety of orthodontic tooth movements are possible, however, it is important to identify the orthodontic treatment purpose and which types of movements are necessary to achieve the desired treatment goals. The ideal orthodontic force differs depending on the type of movement varying from 10 grams to 120 grams. For example, a bodily tooth movement would require force of 70-

120 gm, while an extrusive movement would require only 35-65 gm of force.[4] Orthodontic extrusion, also known as forced eruption, was defined by Bach (2004) and is when the tooth position is altered by applying tractional forces in all regions of the periodontal ligament to stimulate marginal apposition of crestal bone.[6] Initially, the theory originated when Oppenheim (1940) observed the crestal apposition of bone in an extruded tooth of an animal specimen. He reported that the bone followed the occlusal movement of the extruded tooth, thereby increasing the height of the alveolar crest .[7] Forced eruption was first introduced by Heithersay (1973) and then further developed by Ingber (1974) for restorative purposes.[8, 9] It was suggested as a less invasive alternative management of complex osseous defects, such as isolated bone defects to avoid jeopardize adjacent teeth or anatomy. As years progressed, Salama and Salama (1993) have suggested a systemic approach utilizing forced eruption to manage extraction sites by extruding the compromised teeth before placing in an implant, in order to achieve better osseointegration.[10]

Treatment planning orthodontic extrusion over traditional techniques has various advantages. Extrusion is considered a very conservative procedure as it does not compromise bone or periodontal tissues as extractions often do. Another benefit is avoiding the bone resection of neighboring teeth with surgical crown lengthening. Lastly, forced eruption is considered fairly a simple technique, and does not require complicated tooth movements.[6]

Histologic evaluations of orthodontically extruded teeth have shown that the gingiva and alveolar bone accompany the teeth as they move occlusally and that some bone deposition occurs at the alveolar crest. Oppenheim (1940) reported that with extrusion, a passive apposition of bone occurs. Bone formation occurs due to the widening of the PDL rather than its direct stimulation.[7] The

periodontal ligament widens and tooth becomes loose unlike other tooth movements. This fiber relaxation may account for the slow and even apposition of the bone. Bone remodeling is suggested to occur after the 4-6 weeks of extrusion phase (eruptive phase). The keratinized gingiva remodeling occurs from 4-6 weeks after the movement is complete. The eruptive phase is followed by a stabilization period which is observed in 4 weeks to 6 months of the retention phase.[4] Thus, a decreased risk of relapse is expected, which is notable in teeth with compromised and reduced bone support or pre-implant cases. Nevertheless, further studies on the long-term stability and the incidence of relapse after forced eruption are required.

In selected cases forced eruption has been shown to be useful in treating isolated 1- or 2-walled infrabony defects. The concept of forced eruption is applied to treat teeth where osseous surgery would produce esthetics deformities or result in a sacrifice of supporting bone on adjacent teeth. As tooth movement occurs during the extrusion, the gingival tissue apparatus follows the vertical movement of the root during the extrusive process. Therefore, forced eruption can also promote augmentation of soft- tissue volume through the increasing of the attached gingiva.[9-12] Table 1-1 describes possible clinical situations where extrusion is indicated and some clinical scenarios where it is contraindicated,

Table 1-1: Indications and contraindications of forced eruption/Extrusion movement

Indications	Contraindications
Subgingival or infraosseous lesions (between the cementoenamel junction and the coronal third of the root)	Root proximity

Restoration impinging on the biological width	Ankylosis
Reduction of angular bone defects and isolated periodontal pockets	Hypercementosis
Preimplant extraction	Premature closure of embrasures
when surgical extraction is contraindicated (e.g., in patients receiving chemotherapy or radiotherapy)	Extrusion for restorative reasons if: 1) short roots [crown–root ratio is less than 1:1]. 2) Insufficient prosthetic space. 3) Exposure of the furcation.
Impacted teeth	Vertical root fracture

It is critical to evaluate the consequences of orthodontic movement. Orthodontic intrusion and torqueing of roots into cortical plates are most commonly associated with the reduction of support or root resorption. A systematic review by Weltman (2010) demonstrated that comprehensive orthodontic treatment causes increased incidence and severity of root resorption. The heavy forces might be particularly harmful to the dentition by reducing support.[13] Over the years, orthodontic extrusion has been used as a viable treatment modality for multiple restorative purposes, not just orthodontic treatment. There is limited research evaluating the prognosis of a tooth after the forced eruption has been completed or the longevity of the tooth after the extrusion. Additional studies are required to investigate the success rate and incidence of complications after tooth forced eruption is completed. Therefore, the aim of this study is to evaluate the long-term stability of teeth that were orthodontically treated with forced eruption movement for restorative purposes.

Primary objective:

To determine the success and survival rate of teeth treated orthodontically by forced eruption movement for restorative purposes by calculating the mean retention time from the time of treatment initiation to current date.

Secondary Objective:

To evaluate the clinical parameters of 1) activation time, 2) retention time, 3) total treatment time, 4) crown margin to bone crest before and after eruption 5) root length before and after eruption, 6) compare the difference between anterior and posterior teeth, 7) additional treatment required to restore the teeth, 8) pre/post-surgical complication, and 9) the association between clinician experience and complication rate.

Materials and Methods

This study is an investigator-initiated, retrospective clinical study. Data collection and data analysis was performed by the same one examiner. Clinical data and medical history of patients that underwent forced tooth eruption in Pennsylvania Dental Medicine clinics (PDM) were obtained from the years of 2012 to 2020 using an oral health database (axiUm, Exan Software, Henry Schein). Institutional review board approval was obtained from the University of Pennsylvania prior to collecting any retrospective data from patient axiUm records.

All patient information was collected without any identifiers, codes, links or other means of associating the data to the subject's identity. Demographic variables extracted included age, gender, race, smoking history (past, present), and health status as classified by the American Society of Anesthesiologists (ASA I, II, III or IV).

Inclusion criteria consisted of any patients receiving orthodontic extrusion in PDM between the years of 2012–2020, all ages, systemically healthy (ASA I or II), records that include pre- and post-treatment radiographs. Exclusion criteria consisted of patients with active periodontal disease or acute endodontic infection.

From the electronic medical records, the following variables were extracted: number and locations of teeth involved, technique of forced eruption, duration of forced eruption, activation time, retention period, intrusion of adjacent teeth (if present), width of keratinized tissue, presence of mucogingival defects, fiberotomy, additional requirement of hard or soft tissue surgical procedures

before or after the forced eruption, any complications that occurred during or after forced eruption movement, and radiographic data (pre- and post- extrusion). Radiographic measurements were completed before and after treatment to measure 1) the distance from the crown margin to the crest of the alveolar bone and 2) root length (Figure A).

For the purpose of this study long term prognosis was defined as >1 year.

Figure A. Radiographic Measurement before and after FE

Statistical Analysis:

The Data was analyzed using the PRISM Statistical software program. Percentages, distributions, means, and standard deviations were presented as descriptive data for all clinical variables. A paired *t*-test ($p < 0.05$) was used to assess the distance from crown margin to bone crest and root length before and after forced eruption. A Mann Whitney Test ($p < 0.05$) was used to evaluate the correlation between the need for additional surgical treatment and the distance of extrusion.

Results

Twenty-five (25) participants with a total of thirty-six (36) orthodontically extruded teeth were included in the study. Of the total number of participants, ten (40%) were male, and fifteen (60%) were female. In regard to their health history, eleven (44%) were classified as ASA I and fourteen (56%) were classified as ASA II, with twenty-four non-smokers (96%) and one (4%) smoker (Figure 1). Maxillary (n = 34) and mandibular (n = 2) forcibly extruded teeth included in this study. Of the maxillary teeth, twenty-six (72.2%) were anterior teeth and eight (22.2%) were posterior teeth. For the mandibular teeth, all that were included in the study were posterior teeth.

This study explored reasons for orthodontic inclusion including for prosthetic treatment, implant site development, and esthetic treatment. The prosthetic treatment included seventeen teeth that were extruded teeth due to inadequate crown length, and seven for gingival augmentation in order to vertically augment papillary height (n = 4) or to improve the facial gingival margin (n = 3). Ten teeth were erupted for future implant site development and instead of extraction and additional bone augmentation. Thirty-three were erupted by using fixed appliances and three were completed using removable clear aligners.

To provide adequate extrusion, activation time ranged between 1-4 weeks with a mean of 2.86 weeks for all categories. Occlusal adjustments were made periodically to allow for adequate eruption (Figure 2).

The retention time of the orthodontically extruded teeth were divided into two separate categories. Teeth that were extruded for prosthetic purposes had a retention time between 4-9 weeks with a mean of 5.11 weeks. Teeth that were extruded for implant site development were treated orthodontically for a range of 12-14 weeks with a mean of 12.3 weeks prior to tooth extraction (Figure 3).

The overall treatment period ranged from 3- 16 months with a mean of 7.05 months. The timing for a natural tooth site had a range of 1.2-14 months with a mean of 6.12 months. The timing for implant site development ranged between 4-16 months with a mean 9.2 months (Figure 4).

When comparing the crown margin to bone crest before and after treatment, there was a statistically significant increase ($p < 0.05$) in the crown length (Figure 5). When comparing the root length before and after treatment there was no statistically significant decrease in root length (Figure 6).

When evaluating the crown margin and root length for anterior and posterior teeth, there was a statistically significant increase from the crown margin to bone crest in the anterior teeth ($p < 0.01$) and posterior teeth ($p < 0.001$) (Figure 7). When comparing root length for anterior and posterior teeth, both showed non-significant differences ($p > 0.05$) (Figure 8).

Amongst the teeth that underwent forced eruption, it was noted that when more than 1mm extrusion was completed, there was a statistically higher chance that the tooth required additional surgeries ($p < 0.05$) (Figure 9). Additional treatments that the extruded teeth underwent included

fibrotomy alone (n = 3), gingivectomy alone (n = 2), fibrotomy and gingivectomy (n = 1), and crown lengthening (n = 5) (Figure 10). In sites where the tooth was erupted for implant site development, nine of the teeth were extracted with immediate implant placement and one site was extracted and ridge augmentation procedures were completed for delayed implant placement (Figure 11).

Survival rate and post-treatment complications of the extruded teeth were also examined. Twenty-five (96%) of the teeth survived and one (4%) failed after being deemed non-restorable due to caries and was planned for extraction 3 years later (Figure 12). It was noted when the clinician had orthodontic training the complication frequency was 10% , and when the clinician did not have orthodontic training the percentage of complication increased to 43% (Figure 13).

Figure 1. Patient demographics.

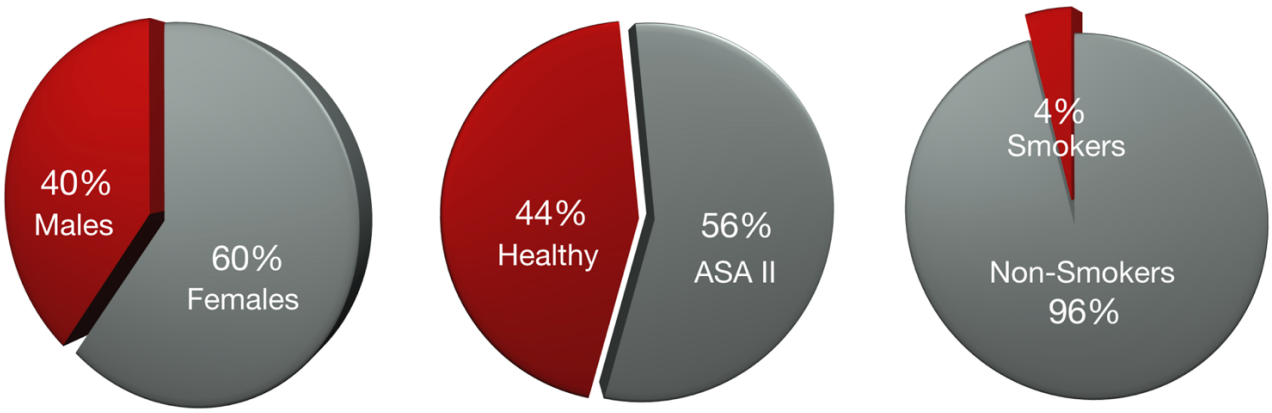


Figure 2. Orthodontic activation time.

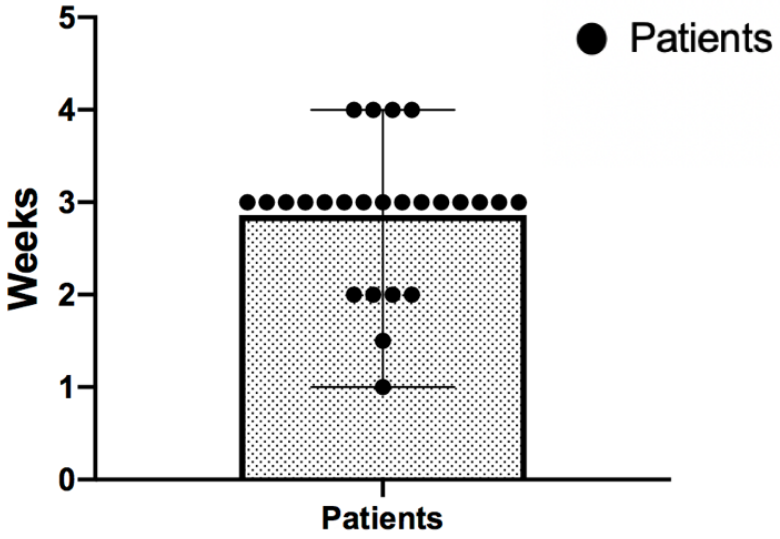


Figure 3. Retention period before prosthetic treatment.

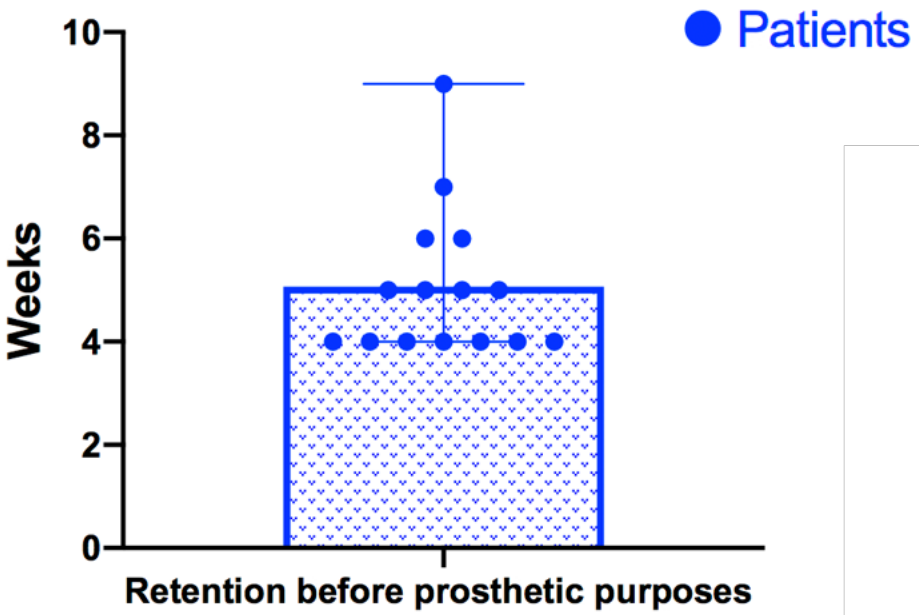


Figure 4. Retention period before tooth Extraction.

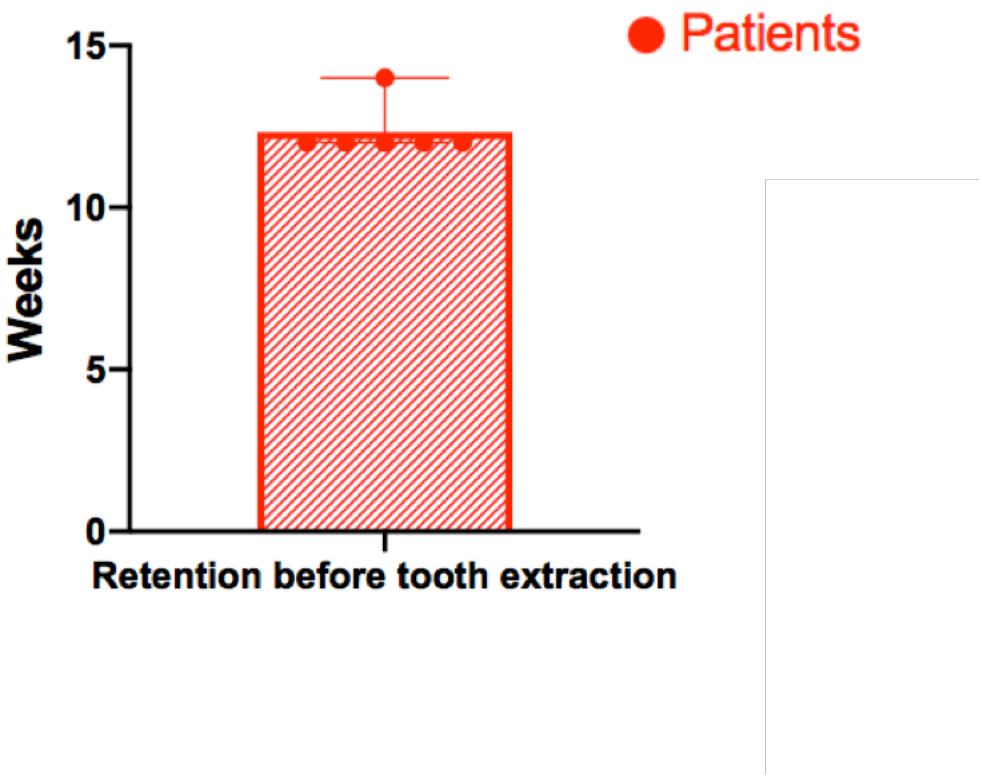


Figure 5. Retention period.

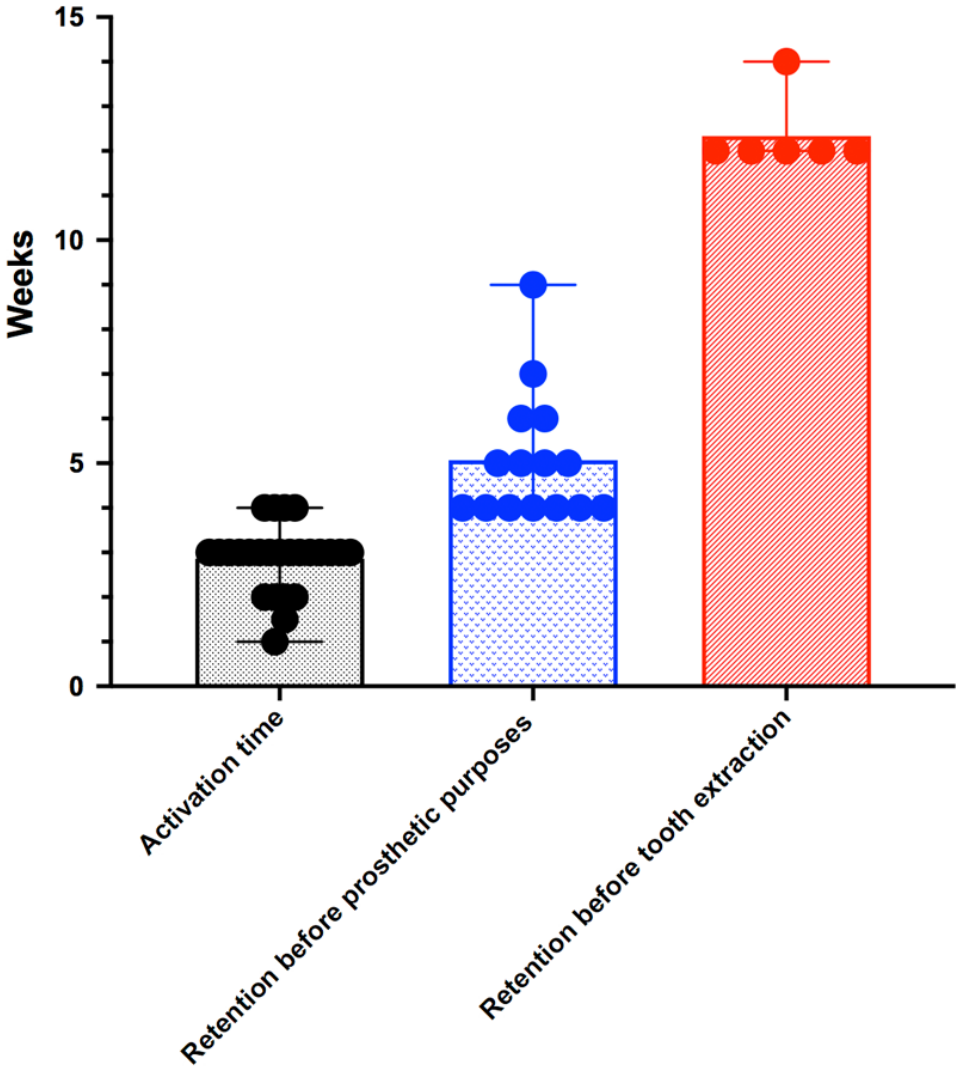


Figure 6. Crown margin changes with forced eruption.

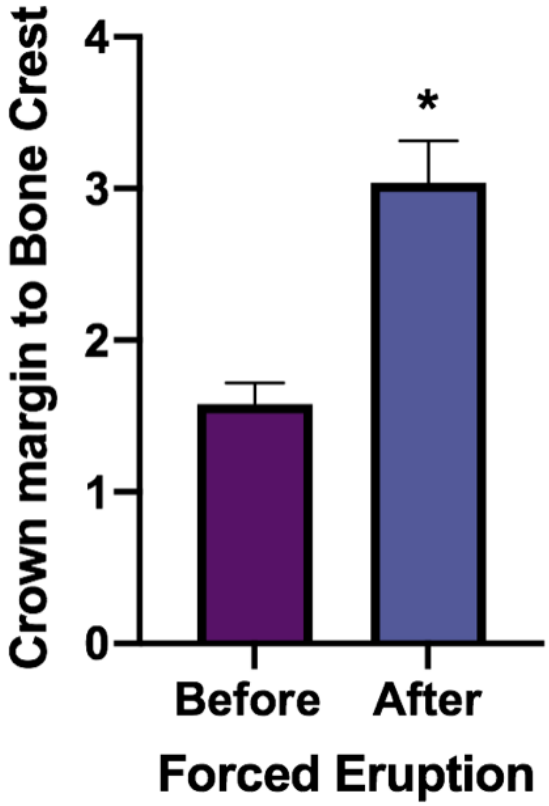


Figure 7. Root length changes with forced eruption.

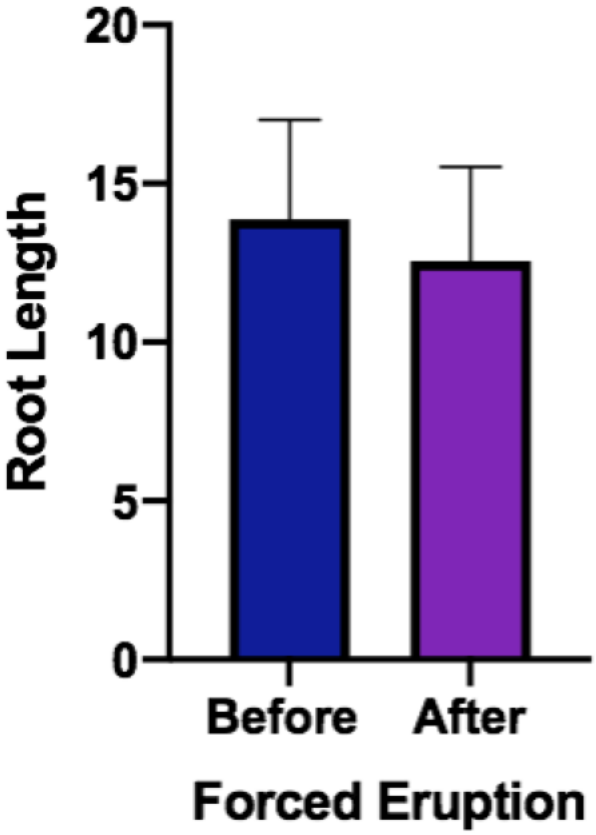


Figure 8. Crown margin analysis in anterior and posterior teeth before and after forced eruption.

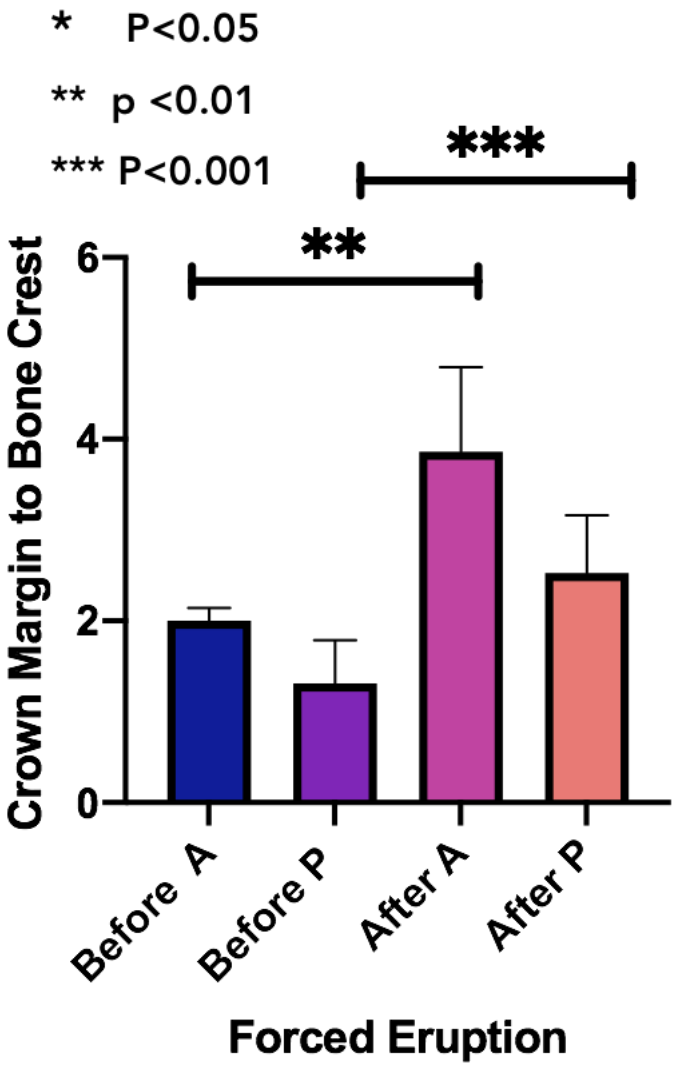


Figure 9. Root length analysis in anterior and posterior teeth before and after forced eruption.

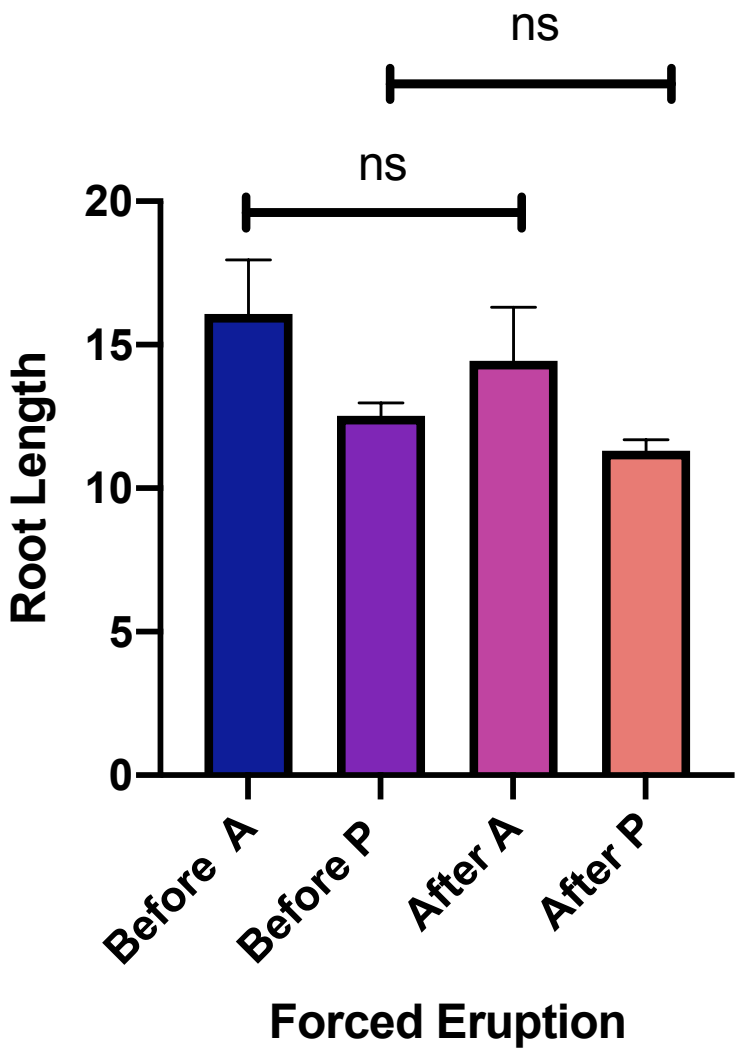


Figure 10. Additional surgical procedures required with forced eruption.

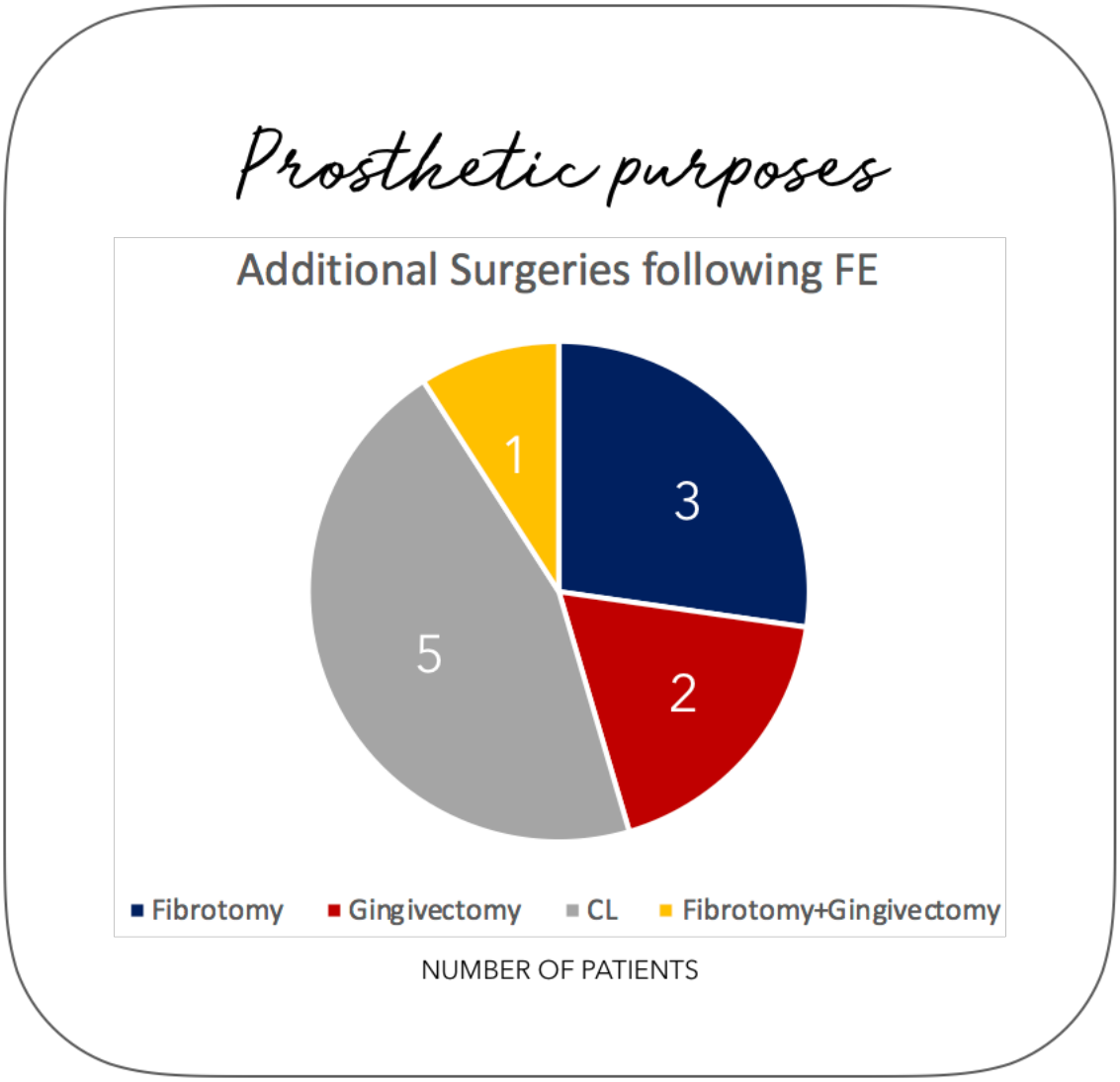


Figure 11. Sites treated with forced eruption for implant site development.

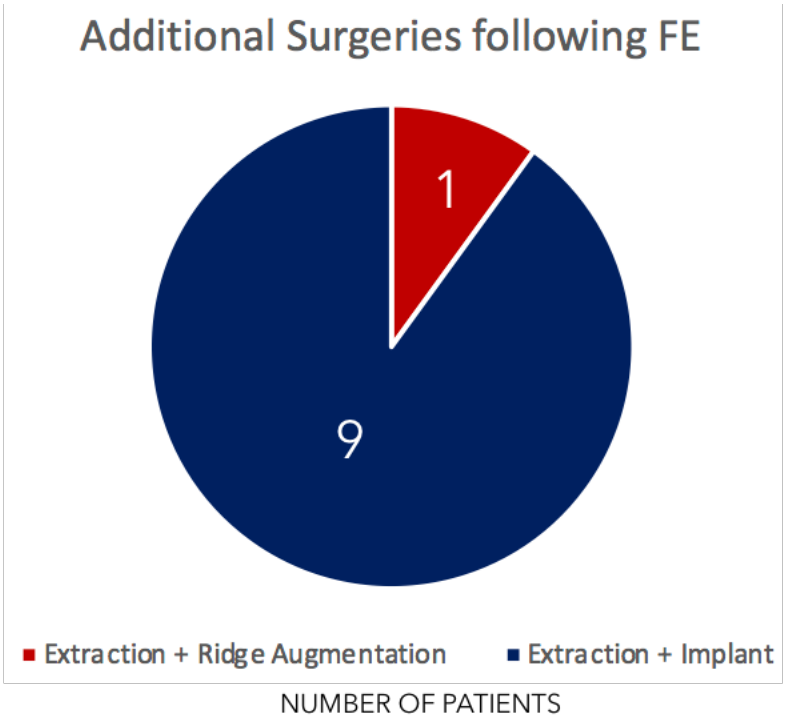
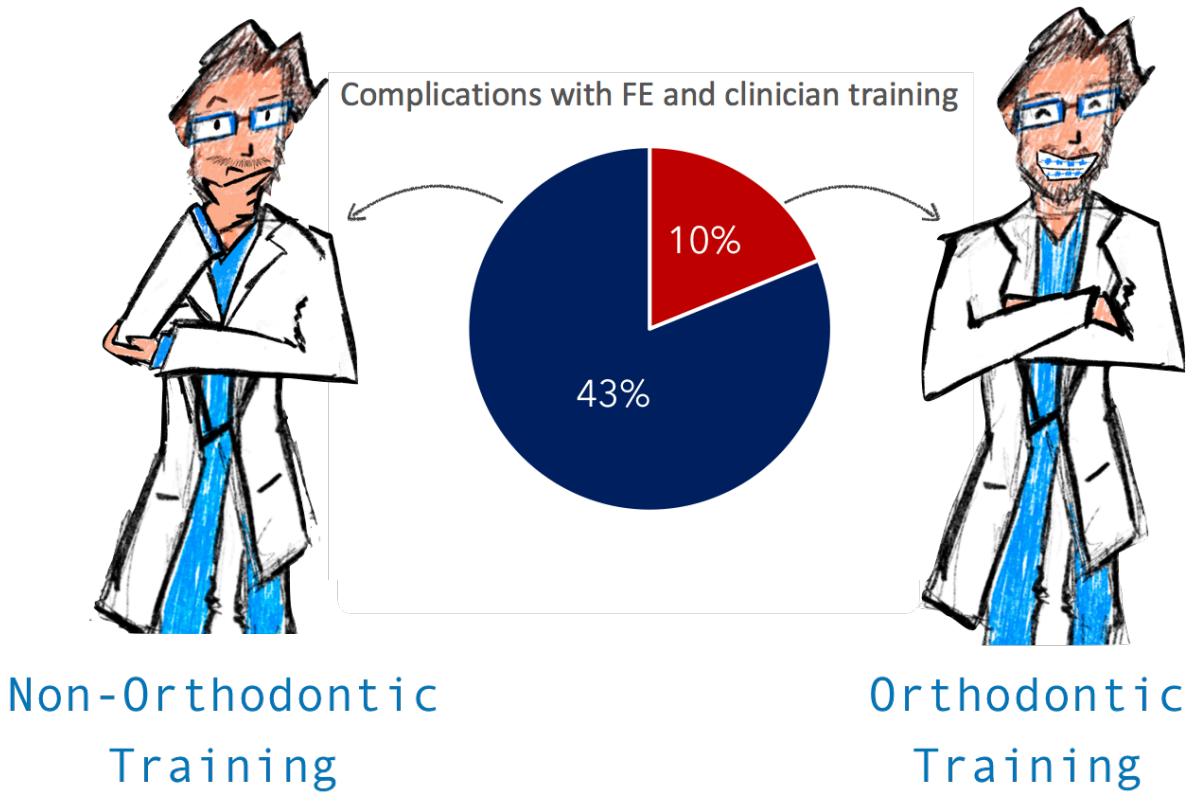


Figure 12. Survival rate of extruded teeth.

Figure 13. Complication rate associated with orthodontic training levels.



Discussion

Forced eruption, otherwise known has orthodontic extrusion, is most commonly performed in the maxilla relative to the mandible, as it is often driven by the esthetic demand attributed to the maxillary smile line. This study examined the sequelae of using orthodontic extrusion for two purposes 1) to achieve prosthetic goals by retaining the tooth, or 2) for implant site development by eventually extracting the tooth.

There are two main ways to complete forced eruption. The first is through fixed appliances which was first proposed by Ingber (1974) and the second is through removable appliances (clear aligners). [9] The advantage of a fixed appliance is that it provides the clinician with full control of the movement, removing the variability of patient compliance and creating a more predictable treatment period (figure 14). In fixed appliances, a ligature can be tied to the bracket slot, around the wings of a bracket, or a wire can be bonded to the tooth with composite (figure 16 & 17). In cases where removable appliances were used, patient compliance a factor that hindered a fixed treatment period. With a removable appliance, the patient changes the aligner every week to allow for movement. In these cases, limited movement can be done and often time is a factor in treatment along with compliance. In these cases, the last aligner can be used as a retainer for the tooth position (Figure 15). It was also noted that it was more effective for the attachment to be placed on both the buccal and lingual surfaces of the extruded tooth to provide more control in the tooth movement through the clear aligners. In this study both appliances required recall for additional activation with appointments ranging between 1-4 weeks (mean recall of 3 weeks). Pre-adjusted edgewise appliances with rectangular wires should be used with small activation increments to

control tooth movement in three-dimensions.[14] This minimizes complication risk of buccal dehiscence due to loss of torque. For prosthetic treatment plans, a loss of torque could be detrimental for esthetic purposes as it may cause increased root prominence or root dehiscence leading to recession. Generally, the slower activation period with a rectangular wire has been proven to have the most predictable outcome.[15] Throughout the movement, periodic occlusal adjustments are required to create space for the teeth to erupt without undergoing traumatic occlusion.

Generally, a shorter treatment period is required for sites undergoing orthodontic extrusion for prosthetic purposes compared to implant site development. With implant site development, more time is required for the alveolus to mature to allow for immediate implant placement with adequate stability. Part of evaluating treatment period includes not only the period in which the extrusion occurs but also the need for any additional surgical procedures after the extrusion to complete the case. For prosthetic cases of using extrusion to increase crown length, a fiberotomy is completed prior to extrusion to aid in orthodontic movement. A fiberotomy, as discussed by Pontoriero (1987), involves severing the connective tissue attachments around the tooth on a regular basis. [16] When performed on a weekly basis, the teeth showed a successful outcome for decreasing the attachment apparatus. This study demonstrated that in cases which had fiberotomy between 1.5 to 3 weeks after orthodontic initiation did not need any additional surgeries after the forced eruption was completed. This suggests that periods greater than one week between fiberotomies decreases the chances of the need of an additional surgery. In cases where the fiberotomy was completed in the middle of orthodontic extrusion, the case required an additional gingivectomy at the completion of the procedure for an esthetic outcome.

The comparison of post-treatment radiographs to baseline showed that there was an increase in crown length however there was not a significant decrease in root length, thus suggesting that orthodontic extrusion does not compromise the crown to root ratio. In regard to the extrusion distance, when teeth were extruded >1 mm, additional surgical treatment was required. The most common adjunctive surgical procedure was crown lengthening. Teeth that were planned for extraction at the end of orthodontic extrusion were due to caries and non-restorability, not periodontal complications. None of the erupted teeth required scaling and root planning. The total survival rate of the tooth that had forced eruption was 96% indicating that orthodontic extrusion is a viable, successful treatment option for prosthetic, implant site development, and esthetic treatment goals. The long-term prognoses of these teeth were deemed favorable overall with an average follow up period of 3 years that ranged between 1-7 years follow after forced eruption and the teeth were still in function.

Complication frequency was significantly increased with clinicians that were not trained orthodontically. Of the complications documented, one of the complications resulted from using a round wire which resulted in the loss of torque of the teeth leading to a buccal dehiscence (Figure 18). Based on this complication, the clinician documented that the optimal technique for forced eruption is to use rectangular wires to maintain adequate torque throughout. Management of this complications can be completed via providing adequate torque through a bend in the wire, by torqueing the auxiliary, or through root plasty (Figure 19-21).

This retrospective study provides insight into the longevity of teeth extruded for prosthetic and implant site development purposes. The following limitations must be considered, conclusions cannot be extrapolated to the general population due to the sample size with incomplete data sets from each chart. Additionally, the radiographs used for measurements for the crown and root lengths were not standardized. Future prospective studies should be completed to investigate the maximum time needed between fiberotomies to mitigate the need for additional surgeries and to evaluate the effect of extrusion on keratinized tissue.

Figure 14. Trays not tracking well due to issues with patient compliance

Figure 15. Stabilization technique

Figure 16. Stabilization technique (Courtesy of Dr. Abdulrahman Aseeri)

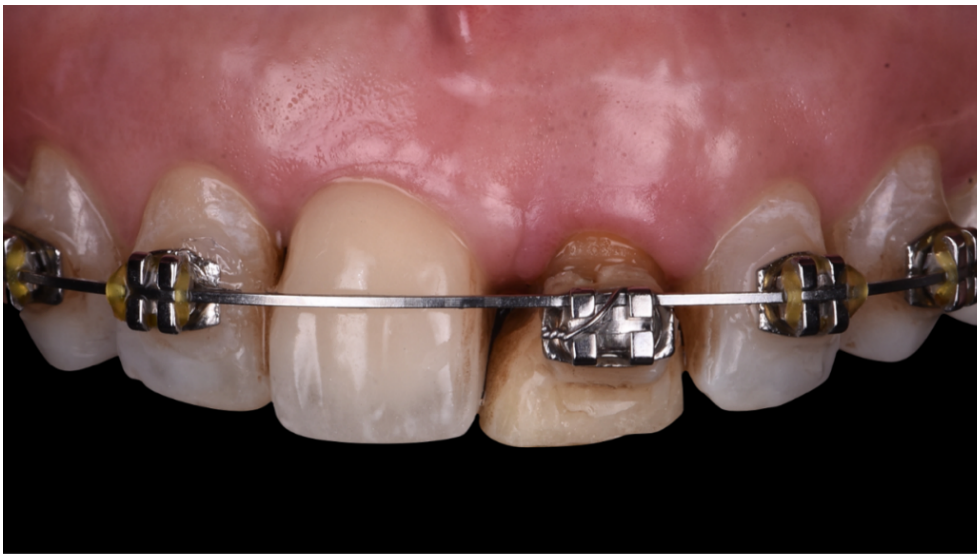


Figure 17. Stabilization techniques. (Courtesy of Dr. Tunjan Wang)

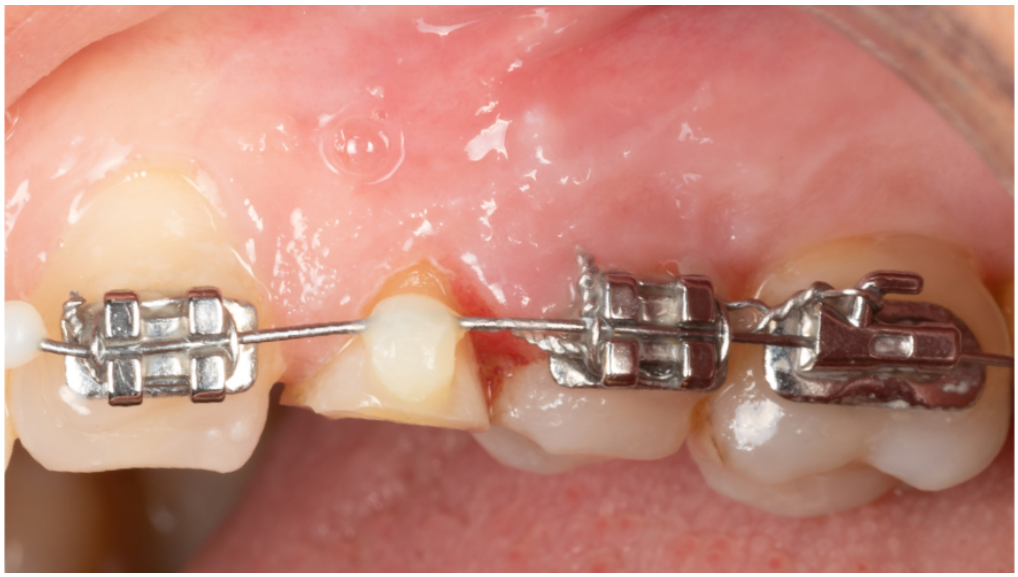


Figure 18. Buccal fenestration complication visible upon flap reflection. (Courtesy of Dr. Tunjan Wang)

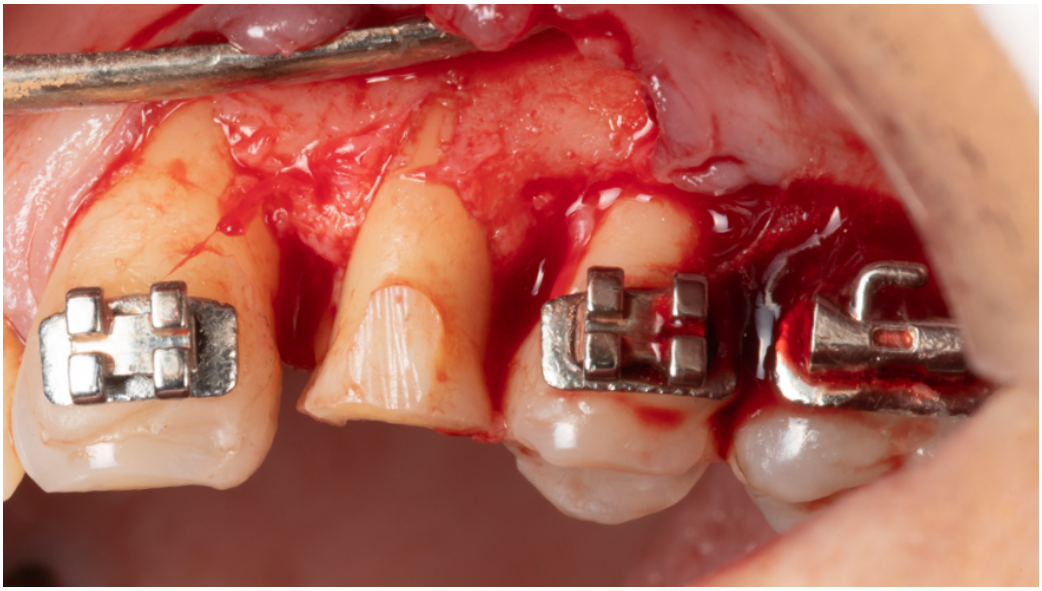


Figure 19. Root Dehiscence before plasty.

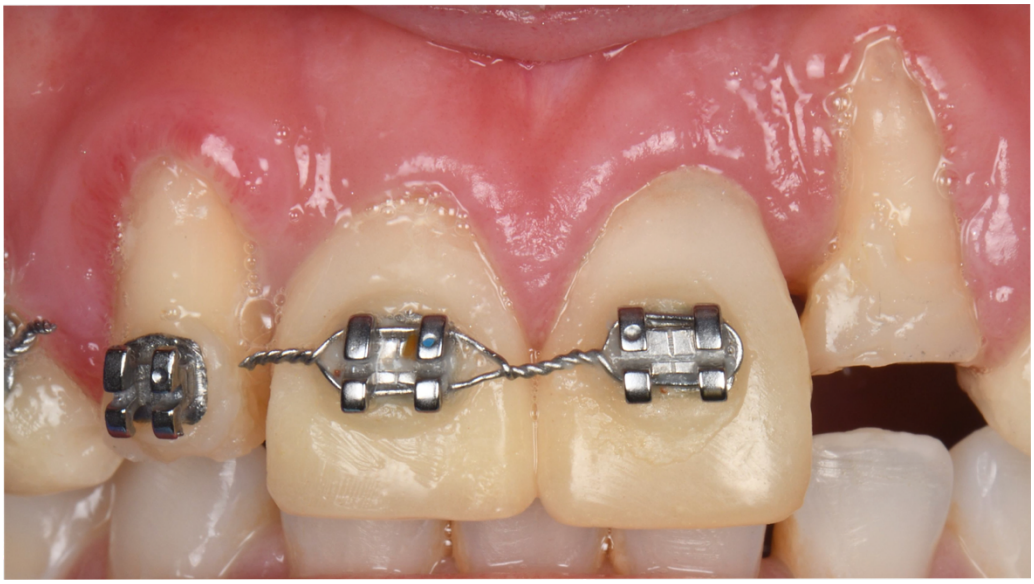


Figure 20. Showing the root plasty.

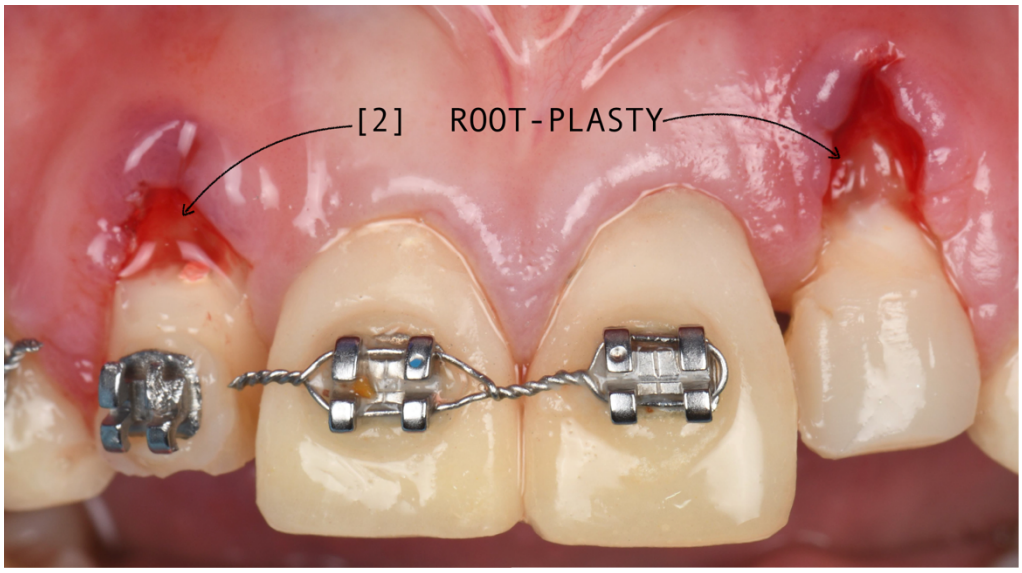


Figure 21. Management of complication via root plasty (Case courtesy of Dr. Wael Isleem)

Conclusion

Forced eruption for prosthetic treatment and implant site development is successful in the long-term (>1 year). Careful considerations should be made with proper case selection (by using rectangular arch wire to express root torque and avoid buccal alveolar bone dehiscence). Additional surgeries may be required for forced eruption cases with the most common being crown lengthening.

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Biographical Sketch

Mohammad Qali was born and raised in Kuwait. He earned his Doctor in Dental Surgery at Virginia Commonwealth University in May 2015. He then returned to Kuwait City for a one year AEGD internship program at the Kuwait Ministry of Health, of which he completed in July 2016. In 2017, Dr. Qali joined the Kuwait University as a teaching assistant in the Department of Periodontics. He is currently a senior resident in combined Periodontics/Orthodontics program at the University of Pennsylvania and anticipates graduating in June 2021 with a certificate in periodontics, orthodontics, and dentofacial orthopedics. He will also earn his Master in oral biology. Following graduation, he plans to return to Kuwait where he will be a practicing clinician and an academician.