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Neodymium–doped Yttrium Aluminum Garnet Laser Use at Dental Extraction Sockets: A Consecutive Case Series

by

Alicia Y. Choi, DMD

Thesis submitted to the Faculty of the Army Postgraduate Dental School,
Uniformed Services University of the Health Sciences
In partial fulfillment of the requirements for the degree of
Masters in Oral Biology

THESIS APPROVAL SHEET

Neodymium–doped Yttrium Aluminum Garnet Laser Use at Dental Extraction Sockets: A Consecutive Case Series

This thesis is submitted by Alicia Y. Choi and has been examined and approved by an appointed committee of the faculty of the Uniformed Services University of the Health Sciences.

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DEDICATION

To my husband, my son, my mom, my dad, my sister, my father-in-law, and my mother-in-law.

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8 June 2020

ABSTRACT

"Neodymium–doped Yttrium Aluminum Garnet Laser Use at Dental Extraction Sockets: A Consecutive Case Series"

Alicia Y. Choi DMD, 2020

Thesis directed by: Thomas M. Johnson, DMD, MS, Associate Professor, Department of Periodontics, Army Postgraduate Dental School, Uniformed Services University of the Health Sciences

Background: In contemporary periodontics, multiple techniques for containing bone grafts at dental extraction sockets are available. Many techniques involve gingival flap reflection and placement of a resorbable or nonresorbable barrier membrane. While these methods effectively mitigate the loss of alveolar ridge volume that accompanies tooth extraction, membrane placement adds cost and has been associated with complications. Neodymium–doped yttrium aluminum garnet (Nd:YAG) laser use at extraction sites may simplify treatment and offer practitioners a useful option for extraction socket management.

Methods: Neodymium–doped yttrium aluminum garnet (Nd:YAG) laser irradiation was used to contain particulate bone biomaterial at 20 ridge preservation and 14 immediate implant sites. Laser energy was applied in a three-step process involving deep insertion of the optical fiber, superficial fiber insertion, and photobiomodulation in noncontact mode.

Results: In every case, laser generated blood clots provided immediate graft containment. No complications such as excessive pain, swelling, or infection were noted at postoperative visits. Thirteen (93%) immediate implant and 20 (100%) ridge

preservation sites exhibited favorable healing and positive clinical outcomes. One (5%) Elian class 2 molar site exhibited minor reduction in alveolar ridge volume following ridge preservation. One (7%) immediate implant failed. Eight ridge preservation patients were unavailable for implant surgery due to departure from Fort Gordon (seven) or active orthodontic therapy (one). Of the remaining 12 ridge preservation sites, all 12 (100%) supported implant placement. The clinical quality of the bone was consistently favorable.

Conclusions: Nd:YAG laser irradiation consistently produced clot stability and graft containment without need for barrier membranes at ridge preservation and immediate implant sites. Nd:YAG laser ridge preservation appears to be a viable option for implant site development. Ridge preservation techniques that involve barrier membrane placement may be preferred at Elian Class 2 extraction sockets.

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CHAPTER 1: BACKGROUND

Erbium, chromium–doped yttrium scandium gallium garnet (Er,Cr:YSGG, 2,780 nm) and neodymium–doped yttrium, aluminum, garnet (Nd:YAG, 1,064 nm) lasers have been used clinically in conjunction with immediate implant placement.[1–4] These lasers have very different absorption profiles5 and thus dissimilar intended purposes in immediate implant procedures. Er,Cr:YSGG laser output is highly absorbed in hydroxyapatite, allowing efficient cutting of hard tissue.[5,6] In dog mandibles, Er,Cr:YSGG laser energy produced fine cuts with sharp edges, smooth walls, and no evidence of melting or carbonization.[6] For this reason, one author recommended Er,Cr:YSGG laser use at immediate implant sites for sectioning teeth, troughing around roots to minimize extraction-related trauma, and initiating precise implant osteotomies.[2] Other reports suggest Er,Cr:YSGG lasers may aid in debridement of infected sockets before immediate implant placement.[3,4]

Unlike Er,Cr:YSGG laser output, Nd:YAG laser energy exhibits negligible absorption in water and hydroxyapatite.[5] As a result, the Nd:YAG is known to be a penetrating rather than superficially-absorbed laser.[5] Nd:YAG laser output scatters within soft tissue and exhibits modest absorption in chromophores such as hemoglobin.[5] The ensuing thermal denaturation of proteins produces a robust coagulation layer along the lased surface.[5] Nd:YAG laser energy has been used at an immediate implant site to facilitate containment of freeze-dried bone allograft (FDBA) particles within a peri-implant gap defect.[1]

A third laser type has been evaluated for possible beneficial effects in peri-implant bone. In a rabbit model, gallium-aluminum-arsenide (GaAlAs, 830 nm) diode

laser irradiation produced greater bone-to-implant contact (BIC) compared with non-irradiated controls.[7] The present case series demonstrates Nd:YAG laser irradiation at immediate and delayed implant sites to stabilize blood clots and contain FDBA.

CHAPTER 2: METHODS

All patients in this consecutive case series presented to the Department of Periodontics, Army Postgraduate Dental School, Uniformed Services University of the Health Sciences, Fort Gordon, Georgia. Each patient completed an informed consent process involving verbal and written components and required tooth extraction with either immediate implant placement or alveolar ridge preservation. Nd:YAG laser energy was applied when, in the judgement of the periodontist supervising the case, the technique was most appropriate for the clinical situation.

In each case, a particulate bone biomaterial was placed in an extraction socket or a peri-implant gap defect adjacent to an immediate implant. Graft containment was achieved by stabilizing a blood clot over the biomaterial using an Nd:YAG laser in three steps (Table 1). In the first step, the optical fiber is inserted into the graft and pressed firmly against the socket wall (coronal portion of the alveolus). The laser is activated in contact with alveolar bone and withdrawn over a period of ≈ one second (3.6 W, 650 μs, 20 Hz). Laser activation is terminated once the optical fiber exits the extraction socket. The photoacoustic effect of the laser will eject biomaterial particles during this step. An instrument is used to gently condense the biomaterial particles into the alveolus as needed. This process is repeated at ≈ six to ten locations around the circumference of the site, depending upon socket dimensions.

In the second step of the technique, biomaterial particles are again condensed and additional blood is allowed to pool over the socket orifice. The optical fiber is inserted just below the pooled blood surface and activated for ≈ one second. This process is repeated at approximately six to ten locations around the circumference of the site, depending upon socket dimensions.

The final step of the technique, the optical fiber is maintained approximately 2.5 to 3.5 cm away from the site and activated continuously (3.0 W, 100 μs, 20 Hz). The fiber is slowly moved in overlapping circles over the facial, occlusal, and lingual aspects of the extraction socket. The total energy applied in the photobiomodulation step is limited to approximately 200 to 325 Joules.

Table 1: Recommended technique for Nd:YAG laser application at dental extraction sockets

Step	Description	Technique
1	Deep insertion of optical fiber	The optical fiber is inserted into the allogeneic bone derivative and pressed firmly against the socket wall (coronal portion of the alveolus). The laser is activated in contact with alveolar bone and withdrawn over a period of approximately one second (3.6 W, 650 μs, 20 Hz). Laser activation is terminated once the optical fiber exits the extraction socket. The photoacoustic effect of the laser will eject biomaterial particles during this step. An instrument is used to gently condense the biomaterial particles into the alveolus as needed. This process is repeated at approximately six to ten locations around the circumference of the site, depending upon socket dimensions.
2	Superficial insertion of optical fiber	Biomaterial particles are condensed following step 1 and additional blood is allowed to pool over the socket orifice. The optical fiber is inserted just below the pooled blood surface and activated for approximately one second. This process is repeated at approximately six to ten locations around the circumference of the site, depending upon socket dimensions.
3	Photobiomodulation	The clot covering the socket orifice typically appears moist following step 2. After the photobiomodulation step, the clot has a dry appearance. The optical fiber is maintained approximately 2.5 to 3.5 cm away from the site and activated continuously (3.0 W, 100 μs, 20 Hz). The fiber is slowly moved in overlapping circles over the facial, occlusal, and lingual aspects of the extraction socket. The total energy applied in the photobiomodulation step is limited to ≈ 200 to 325 joules. Step 3 typically enhances clot stability and graft containment.

Tables 2 and 3 present individual patient information and Nd:YAG laser exposure for immediate implant and ridge preservation cases, respectively. Clinical photographs documenting treatment are shown in Appendix 1 (ridge preservation sites) and Appendix 2 (immediate implant sites).

Table 2: Patient information and Nd:YAG laser exposure, ridge preservation cases

Case	Age	Sex	Assessment/ diagnosis	Procedure date	Implant	Laser Energy Applied at Extraction (Joules)	Laser Energy Applied at Follow-up (Joules)
1	36	M	Nonrestorable tooth #12 (root caries, vertical root fracture)	4/24/2018	ø4.1 x 13 mm, Zimmer Biomet	364	472 (2 week) 302 (3 week) 309 (6 week)
2	32	M	Not applicable restorable tooth #13 (vertical root fracture, recurrent caries)	6/8/2018	N/A (PCS to S. Korea)	474	302 (1week) 304 (2 week) 301 (4 week)
3	39	M	Nonrestorable tooth #12 (tooth fracture)	6/15/2018	N/A (PCS to FL)	456	290 (7week)
4	52	F	Nonrestorable tooth #13 (periodontally involved, root caries)	11/20/2017	ø4.1 x 11.5 mm, Zimmer Biomet	363	Not applicable
5	42	M	Hopeless tooth #4 (fractured, recurrent caries)	1/24/2019	ø4.1 x 13 mm, Zimmer Biomet	378	304 (2 week) 300 (10 week)
6	49	M	Failed implant #14	9/18/2017	ø5 x 11.5 mm, Zimmer Biomet	375	Not applicable
7	45	M	Failed implant #9	11/13/2018	N/A (PCS to CA)	457	309 (4 week) 303 (7 week)
8	37	M	Hopeless tooth #4 (fractured, inadequate tooth structure)	10/24/2018	Currently under an Orthodontic therapy before implant therapy	Information not available	Not applicable
9	26	M	Over-retained primary tooth #K (root resorption and ankylosed)	1/16/2019	ø5 x 11.5 mm, Zimmer Biomet	403	299 (1 week) 282 (3 week) 217 (5 week)
10	41	M	Nonrestorable tooth #4 (carious, periodontally involved with mobility)	2/25/2019	N/A (PCS to Japan)	380	297 (1 week) 300 (2 week) 301 (4 week)

Table 2 (continued): Patient information and Nd:YAG laser exposure, ridge preservation cases

Case	Age	Sex	Assessment/ diagnosis	Procedure date	Implant	Laser Energy Applied at Extraction (Joules)	Laser Energy Applied at Follow-up (Joules)
11	28	M	Failed immediate implant #9	5/13/2019	ø4.3 x 16 mm, Nobel Biocare	411	304 (1day) 240 (1week) 301 (2 week) 317 (3 week)
12	50	M	Nonrestorable tooth #5 (root caries)	3/27/2019	ø4.3 x 11.5 mm, Nobel Biocare	300	244 (3week) 321 (5 week)
13	40	F	Over-retained primary tooth #K (root resorption)	2/6/2019	ø 4.1 x 11.5 mm, Zimmer Biomet	Information not available	Not applicable
14	60	M	Failed implant #13	3/29/2019	N/A Pontic site development.	412	Not applicable
15	31	M	Over-retained primary tooth #A (root resorption)	1/9/2019	Direct sinus elevation #4 performed on 9/12/2019	300	Not applicable
16	31	M	Over-retained primary tooth #J (root resorption, periodontally involved)	1/9/2019	Direct sinus elevation #13 performed on 5/8/2019	300	Not applicable
17	50	F	Nonrestorable #21 (root caries, insufficient tooth structure)	5/20/2019	ø 4.1 x 11.5 mm, Zimmer Biomet	423	Not applicable
18	43	M	Failed implant #3	4/4/2019	ø 4.1 x 10 mm, Zimmer Biomet	526	Not applicable
19	34	M	Nonrestorable tooth #30	8/30/2017	ø 5 x 11.5 mm, Zimmer Biomet	Information not available	Not applicable
20		M	Nonrestorable #5 (fracture, insufficient tooth structure)	1/22/2020	Healing period	403	Not applicable

Table 3: Patient information and Nd:YAG laser exposure, immediate implant cases

Case	Age	Sex	Assessment/ diagnosis	Procedure date	Implant	Laser Energy Applied at Extraction (Joules)	Laser Energy Applied at Follow-up (Joules)
1	43	M	Nonrestorable tooth #7 (post and core failure, insufficient remaining tooth structure)	1/5/2017	ø3.5 x 13 mm, Nobel Biocare	370	214 (3 months)
2	51	M	Nonrestorable tooth #8 (fracture)	1/3/2018	ø 4.1 x 15 mm, Zimmer Biomet	348	548 (2 weeks) 203 (4 weeks)
3	50	M	Microdont tooth #10 (poor esthetics and crown to root ratio)	4/19/2018	ø3.5 x 13 mm, Nobel Biocare	400	250 (2 weeks)
4	30	F	Over-retained primary tooth #T with root resorption	1/24/2018	ø4.1 x 13 mm, Zimmer Biomet	382	204 (1 week) 202 (2 weeks)
5	36	M	Nonrestorable tooth #5 (insufficient remaining tooth structure)	6/4/2018	ø4.1 x 13 mm, Zimmer Biomet	326	307 (2 weeks) 298 (6 weeks)
6	52	M	Over-retained primary tooth #J (root resorption and defective restoration)	5/21/2018	ø5 x 8.5 mm, Zimmer Biomet	446	294 (4 days) 275 (10 days)
7	39	F	Nonrestorable tooth #30 (insufficient remaining tooth structure)	2/7/2019	ø5 x 10 mm, Nobel Biocare	324	Not applicable
8	36	M	Hopeless tooth #10 (large periapical cyst at the apex)	2/6/2019	ø3.25 x 13 mm, Zimmer Biomet	356	Not applicable
9	40	F	Over-retained primary tooth #J (root resorption and ankylosed root)	2/6/2019	ø4.1 x 11.5 mm, Zimmer Biomet	Information not available	Not applicable
10	40	F	Over-retained primary tooth #K (root resorption)	2/6/2019	ø5 x 11.5 mm, Zimmer Biomet	Information not available	Not applicable
11	28	M	Nonrestorable tooth #19 (vertical root fracture)	3/11/2019	ø5 x 13 mm, Nobel Biocare	460	Not applicable
12	21	F	Over-retained primary tooth #K (root resorption and ankylosed root)	10/17/2019	ø4.1 x 10 mm, Zimmer Biomet	375	Not applicable

13	35	M	Nonrestorable tooth #30 (insufficient remaining tooth structure)	6/6/2018	ø5 x 13 mm, Zimmer Biomet	398	298 (2 week)
14	50	F	Nonrestorable tooth #5 (root caries, insufficient remaining tooth structure)	3/27/2019	ø4.1 x 13 mm, Zimmer Biomet	430	Not applicable

CHAPTER 3: RESULTS

Twenty ridge preservation sites (Appendix 1) and 14 immediate implant sites (Appendix 2) were included in this case series. In every case, laser generated blood clots provided immediate graft containment, and the time required to complete the procedure was always minimal. No complications such as excessive pain, swelling, or infection were noted at any postoperative visit. Thirteen (93%) immediate implant and 20 (100%) ridge preservation sites exhibited favorable healing and satisfactory clinical outcomes. One Elian Class 2 molar site exhibited minor reduction in alveolar ridge volume following ridge preservation. However, this site still supported implant placement and restoration. One (7%) immediate implant failed. Eight ridge preservation patients were unavailable for implant surgery due to departure from Fort Gordon (seven) or active orthodontic therapy (one). Of the remaining 12 ridge preservation sites, all 12 (100%) supported implant placement. The clinical quality of the bone was consistently favorable.

CHAPTER 4: DISCUSSION

Nd:YAG laser output may positively influence hard and soft tissue wound healing.[8–11] Possible effects of Nd:YAG laser energy, based on animal and in vitro studies, include induction of preosteoblast bone morphogenetic protein-2 expression,[8]

stimulation of osteoblast differentiation,[9] and acceleration of bone regeneration.[10] Nd:YAG laser energy applied in human periodontal pockets suppressed selected pathogens below culture detection limits in 85% of patients.[12] Additionally, Nd:YAG laser irradiation attenuated lipopolysaccharide-mediated inflammatory responses of macrophages and endothelial cells in vitro.[13] Thus, at immediate implant and ridge preservation sites, Nd:YAG laser application possibly promotes bone healing,[8–10] suppresses bacteria,[12] and modulates the inflammatory response.[13]

The present report provides no information regarding potential stimulatory effects of the laser. Pulse duration, pulse repetition rate (pulses per second), average power, fiber diameter, target tissue, fiber-to-target distance, number of laser energy applications, and total energy applied are all alterable irradiation parameters with potential to substantially influence the observed effects.[5,14] Confirmative biologic study is needed to define optimal treatment parameters and understand favorable cellular responses achievable with Nd:YAG laser irradiation, if any occur. Even so, the present report documents clinical effects that practitioners can anticipate when Nd:YAG laser output is applied to extraction sites with the described irradiation parameters. The established blood clots unequivocally contained bone allograft material in every case, and time required for hemostasis was always minimal. A pale membranous substance, presumably fibrin, was noted at follow-up appointments covering the portion of the alveolus not yet protected by keratinized mucosa. Exposed FDBA particles were never observed at any follow-up appointment. Whether the fibrin-like material adequately protects the underlying bone allograft prior to completion of soft tissue healing is unknown. Bone and mucosal contours achieved were consistently favorable, albeit over short follow-up periods.

Two pulse durations were used in the presented cases. When a 650-μs pulse duration is used, the pulse is "on" 6.5× longer compared with a 100-μs pulse. Thus, more time is available during each pulse for the laser energy to heat blood and establish a stable clot.[5,14] Conversely, when a 100-μs pulse duration is used, the energy of the pulse is delivered over a much shorter time period, and the peak power (energy/time) attained during each pulse is much higher.[5,14] High-peak power during each pulse—1,500W when the described photobiomodulation (PBM) settings are used—results in high intensity (power/area) light incident on the target tissue.[5,14] Modest superficial absorption attenuates the energy but permits intense laser light beyond the target tissue surface.[5,14] Practitioners should recognize the potential for lateral thermal damage with excessive or improper Nd:YAG laser use, particularly when long pulse durations are used around dental implants.

CHAPTER 5: CONCLUSIONS

Nd:YAG laser irradiation consistently produced clot stability and graft containment without need for barrier membranes at ridge preservation and immediate implant sites. The photobiomodulation step appears to desiccate the clot and rapidly improve clot stability. The suggestion that Nd:YAG laser irradiation may positively influence peri-implant wound healing has not been validated in controlled clinical studies. Nd:YAG laser ridge preservation appears to be a viable option for implant site development. Techniques that involve barrier membrane placement may be preferred at Elian Class 2 extraction sockets, particularly at molar sites. The described method for

ridge preservation should be compared against conventional techniques in randomized controlled clinical trials.

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Appendix 1: Nd:YAG Laser Ridge Preservation Cases

All patients presented to the Department of Periodontics, Army Postgraduate Dental School, Uniformed Services University of the Health Sciences, Fort Gordon, Georgia. All were periodontally and systemically healthy except as indicated.

Abbreviations

RPG: Ridge preservation graft

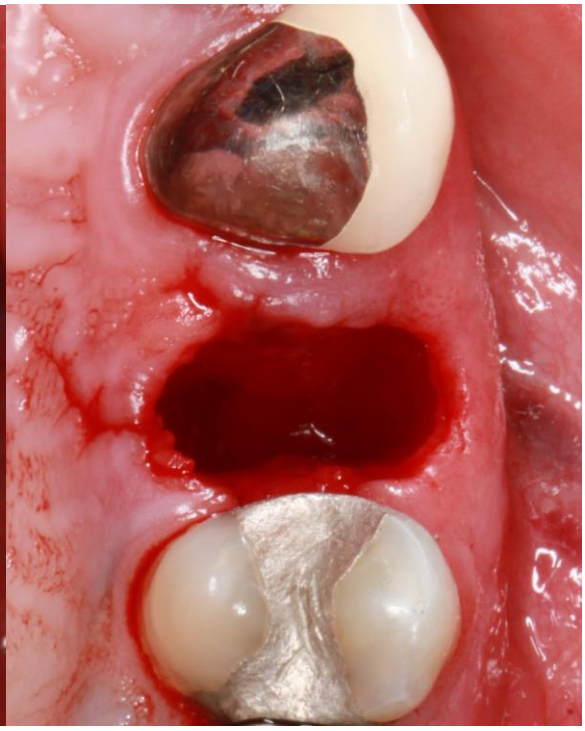
FDBA: Freeze-dried bone allograft

GBR: Guided bone regeneration

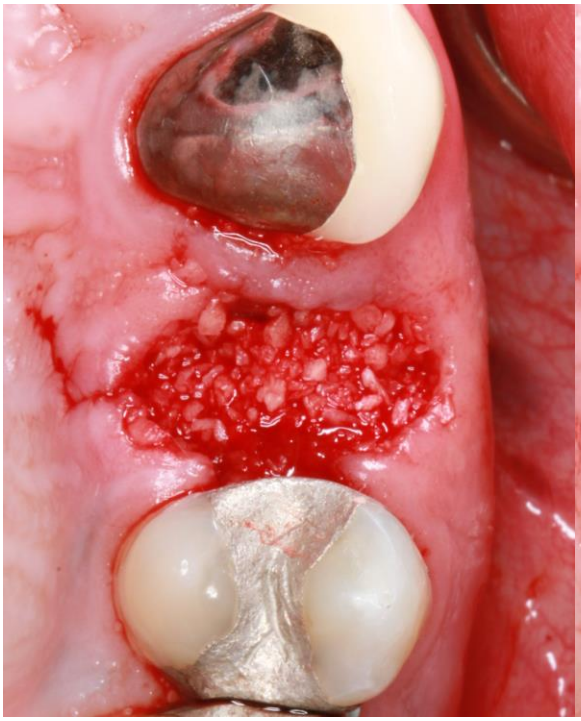
PhII: Implant phase two procedure

Case 1. Surgeon: MAJ Alicia Choi **Date:** 4/24/2018
Diagnosis: Nonrestorable tooth #12 (root caries, vertical root fracture)

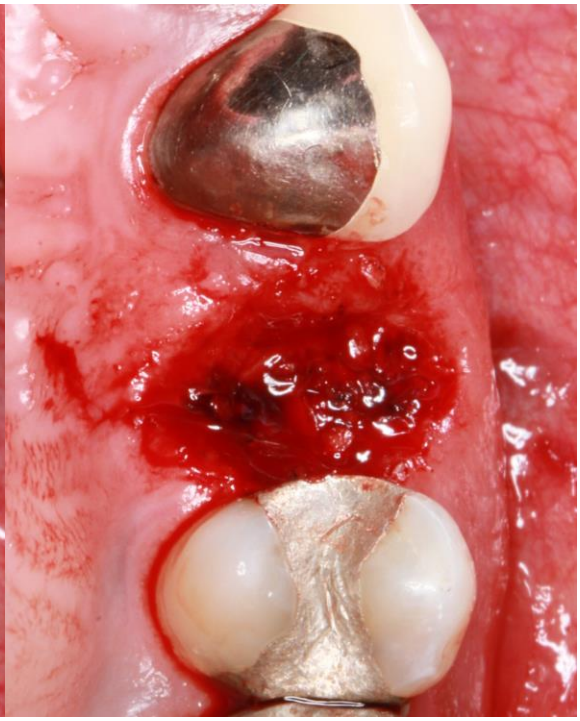
Baseline.



Minimally traumatic extraction.



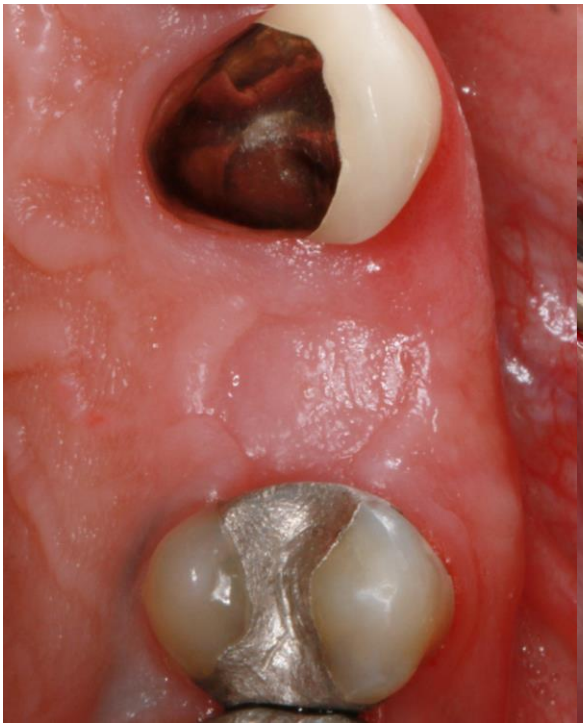
FDBA placed.



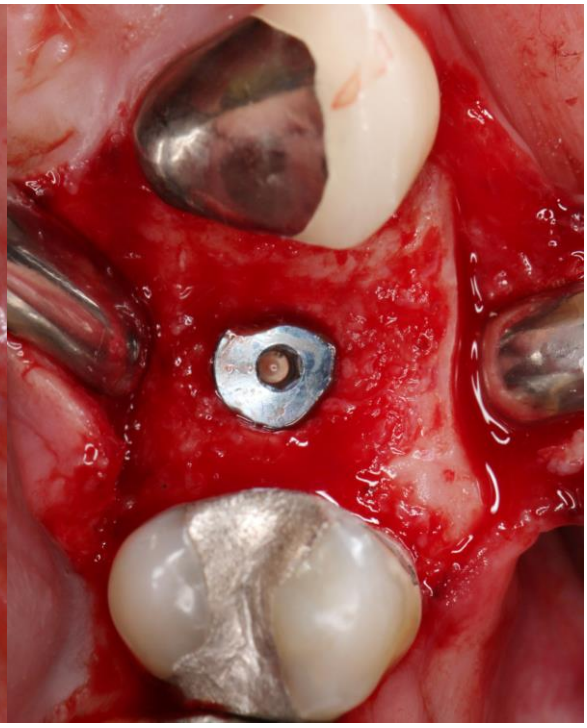
Laser generated blood clot.

Two weeks after RPG.

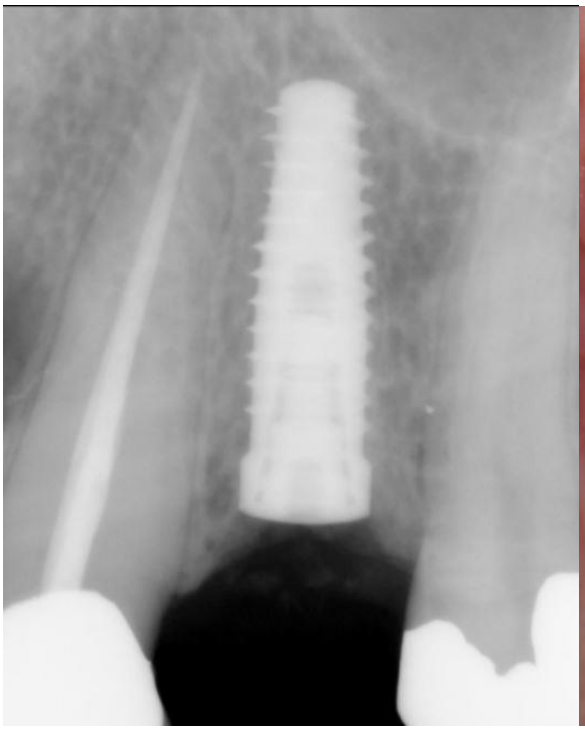
Three weeks after RPG.



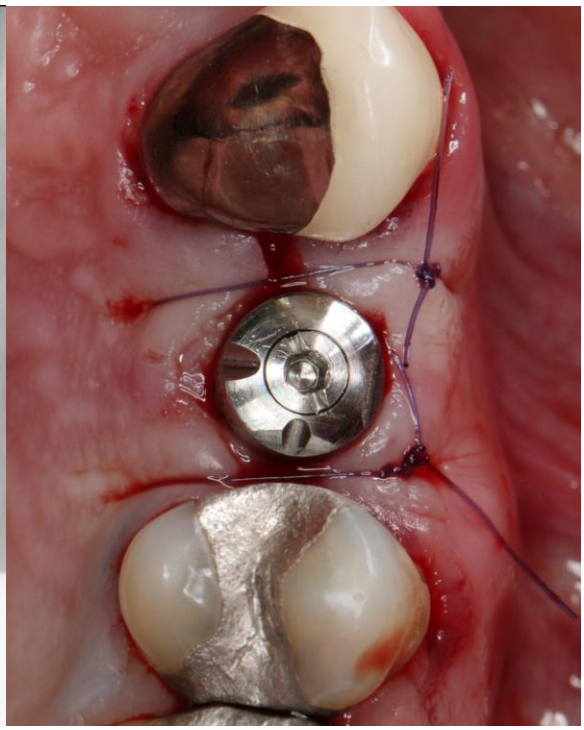
Six months after RPG.



Implant placed.



Radiograph after implant placement.



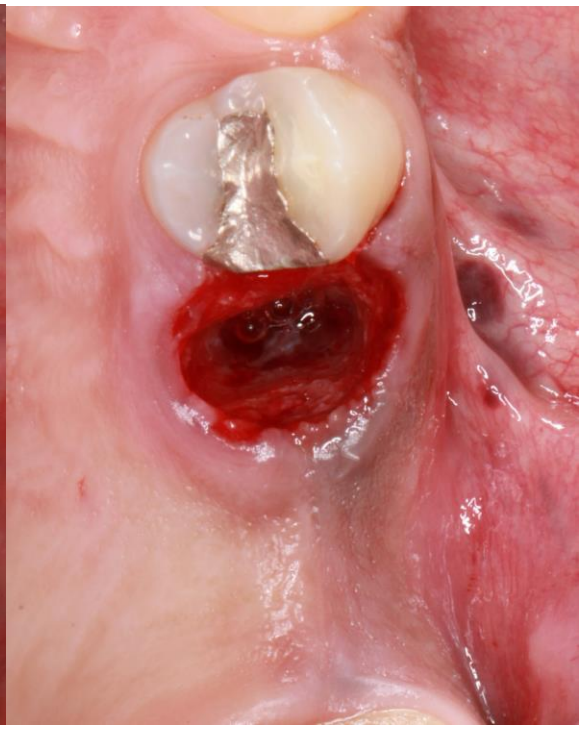
Implant exposure.

Three weeks after implant exposure.

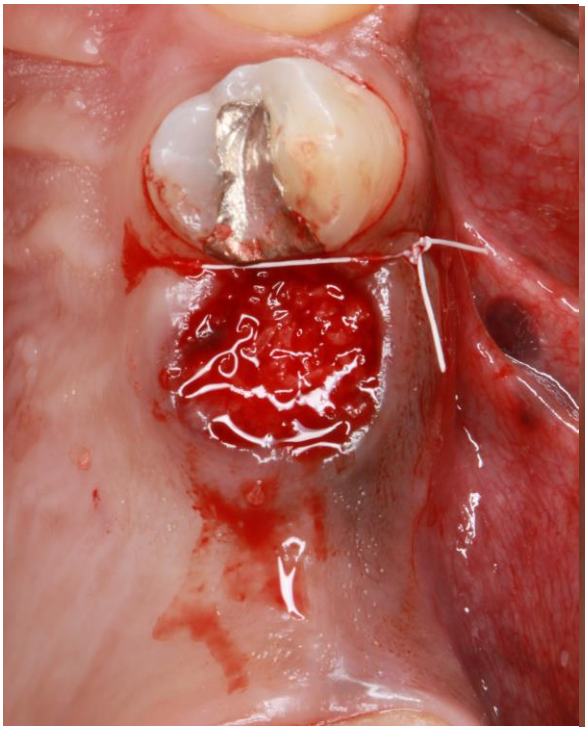
CPT Jenny Oh, Department of Posthodontics, Army Postgraduate Dental School, is currently completing this patient's full mouth rehabilitation.

Case 2. Surgeon: MAJ Alicia Choi **Date:** 6/8/2018
Diagnosis: Nonrestorable tooth #13 (vertical root fracture, recurrent caries)

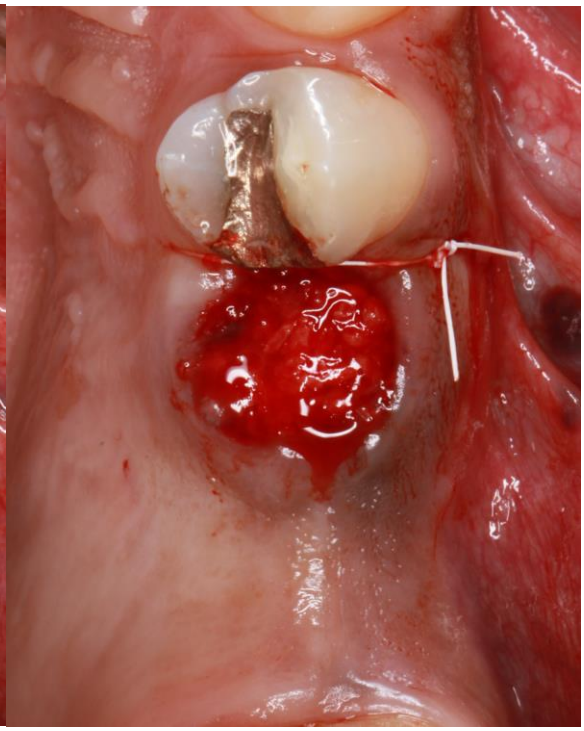
Baseline.



Minimally traumatic extraction.



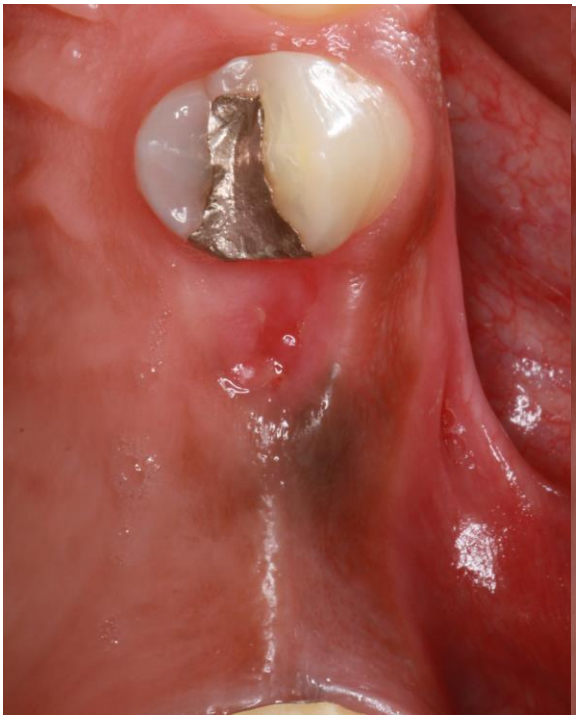
FDBA placed.



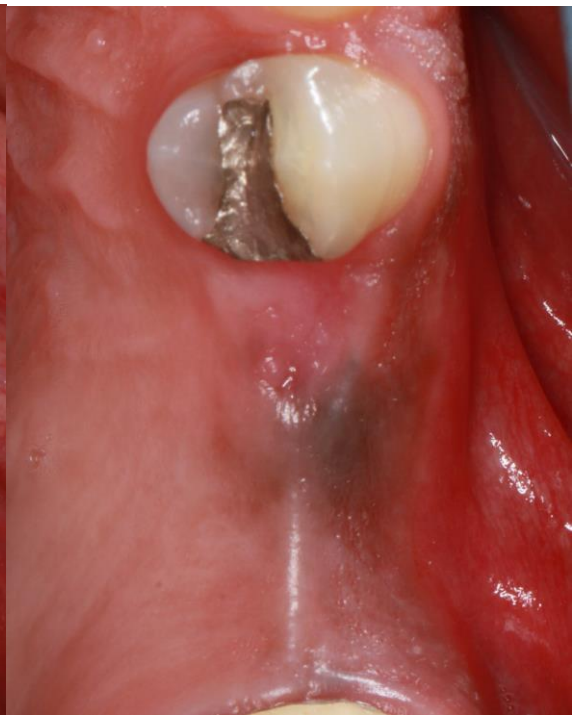
Laser generated blood clot.

One week after RPG.

Two weeks after RPG.



Six weeks after RPG.

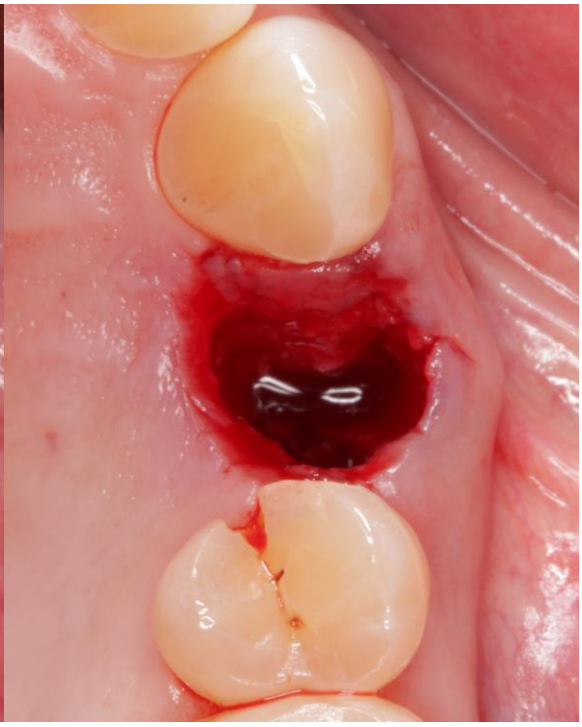


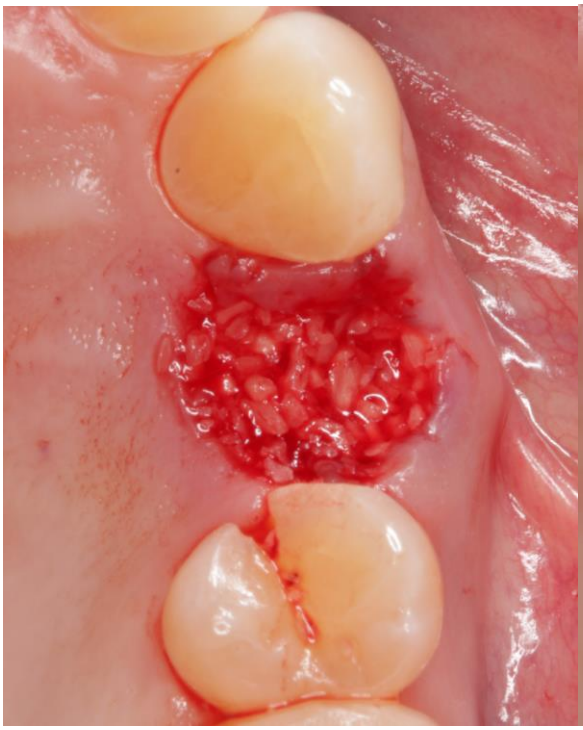
Ten weeks after RPG.

This patient departed Fort Gordon prior to implant placement.

Case 3. Surgeon: CPT Daniel Phillips **Date:** 6/15/2018
Diagnosis: Nonrestorable tooth #12 (vertical root fracture)


Baseline.


Minimally traumatic extraction.


FDBA placed.


Laser generated blood clot.

Two weeks after RPG.

Seven weeks after RPG.

This patient departed Fort Gordon prior to implant placement.

Case 4. Surgeons: MAJ Paul Seibel, CPT Rick Hill **Date:** 11/20/2017
Diagnosis: Nonrestorable tooth #13 (root caries, stage III periodontitis)

Baseline.

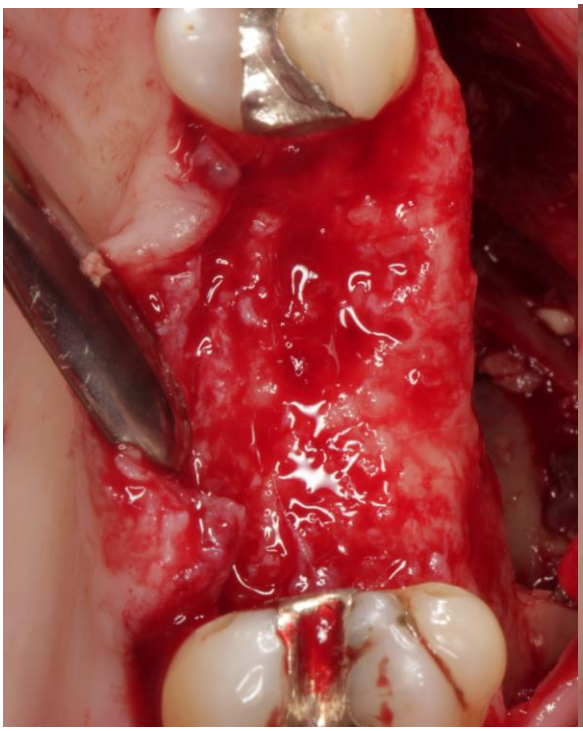
Minimally traumatic extraction.

FDBA placed.

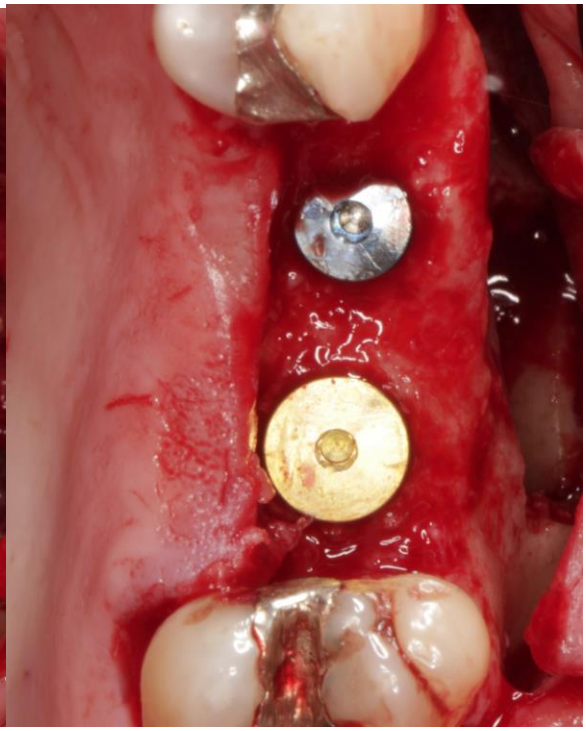
Laser generated blood clot.

One week after RPG.

Four months after RPG.



Flap reflected.



Implant placed with simultaneous lateral sinus elevation.

Wound closure.

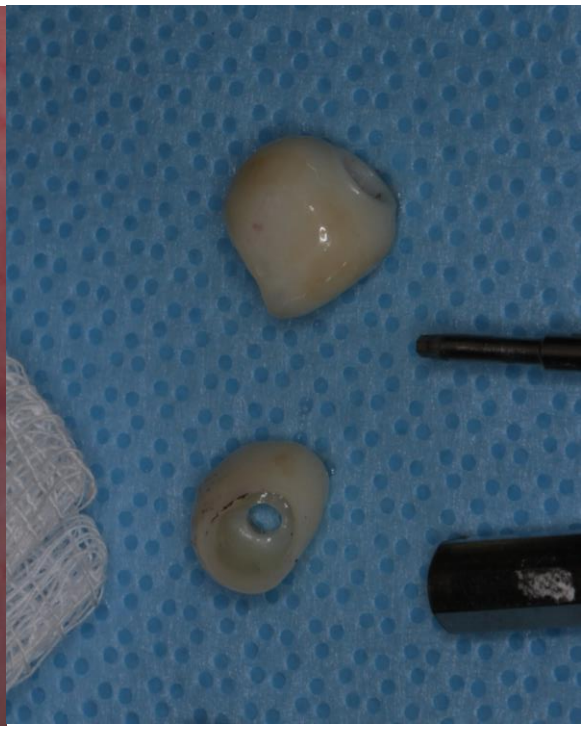
One week after implant placement.

Two weeks after implant placement.

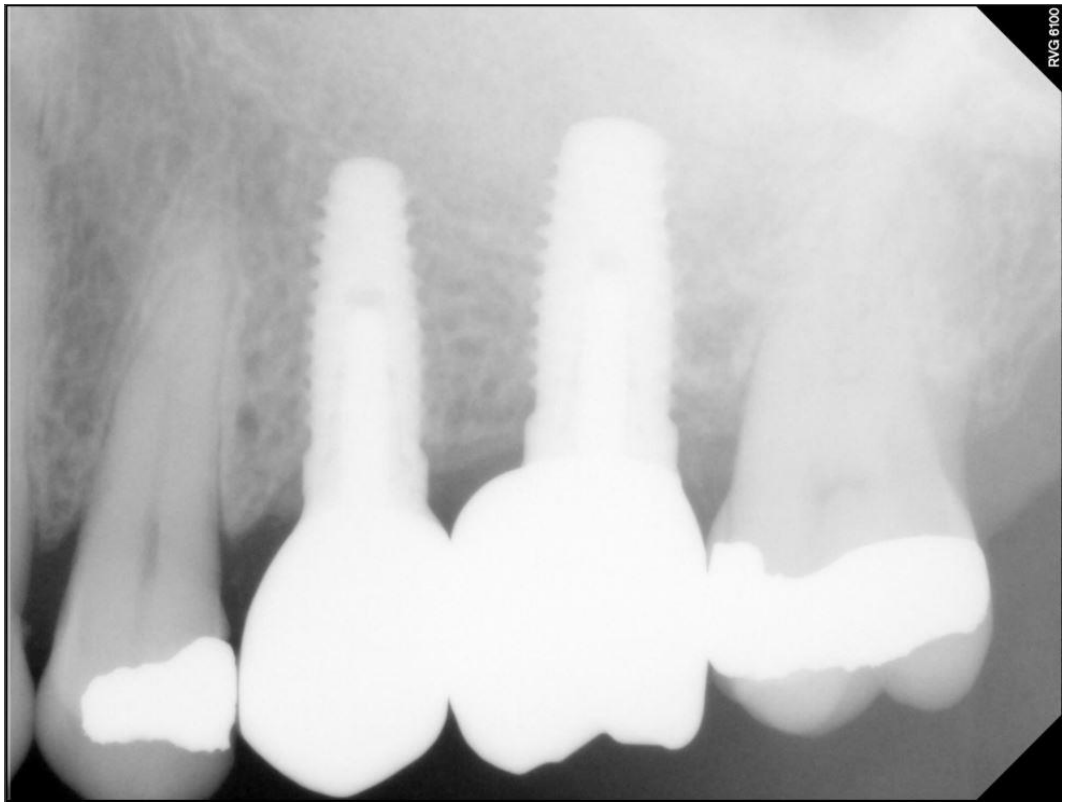
Four weeks after implant placement.

PhII six months after implant surgery.

Implant abutment, two months after PhII.



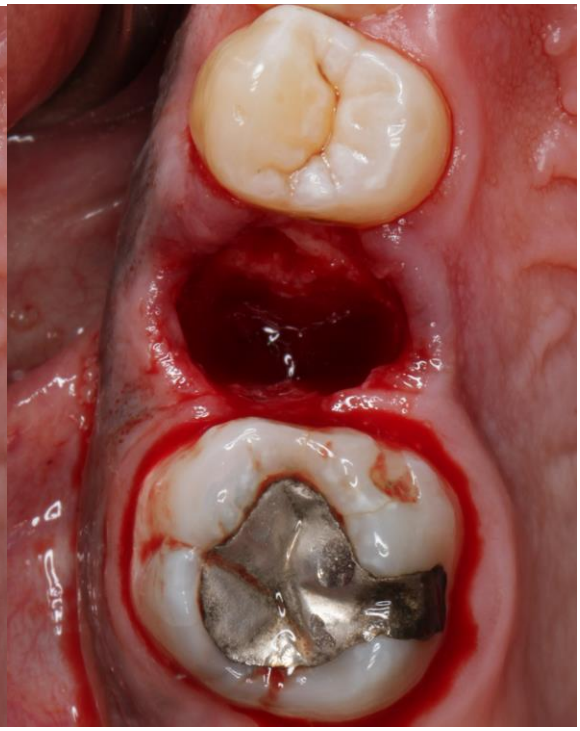
Final restoration delivered two months after PhII, by CPT Kellie O'Keefe, Department of Prosthodontics, Army Postgraduate Dental School.



Periapical radiograph at delivery of definitive restorations.

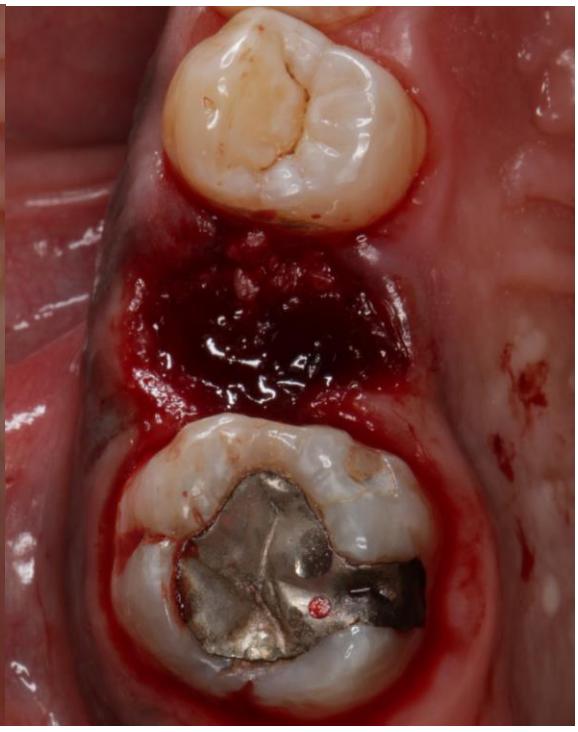
Case 5. Surgeon: MAJ Alicia Choi **Date:** 1/24/2019
Diagnosis: Nonrestorable tooth #4 (fracture, recurrent caries)

Baseline.



Minimally traumatic extraction.

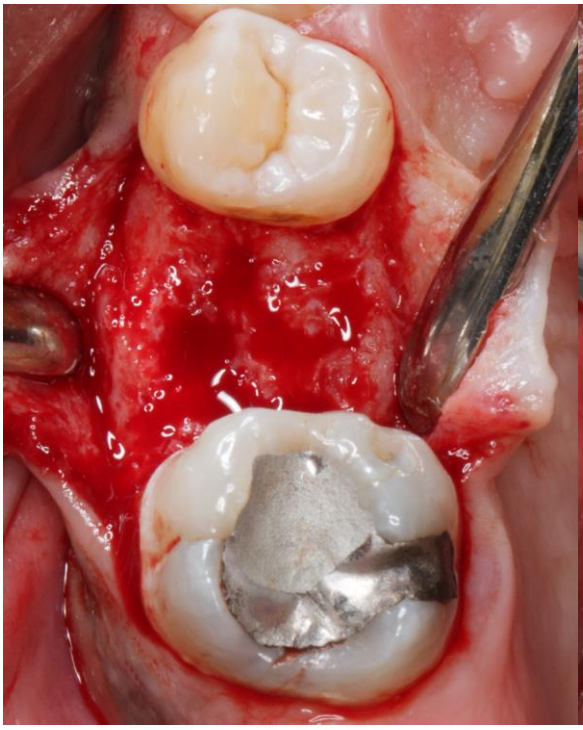
FDBA placed.



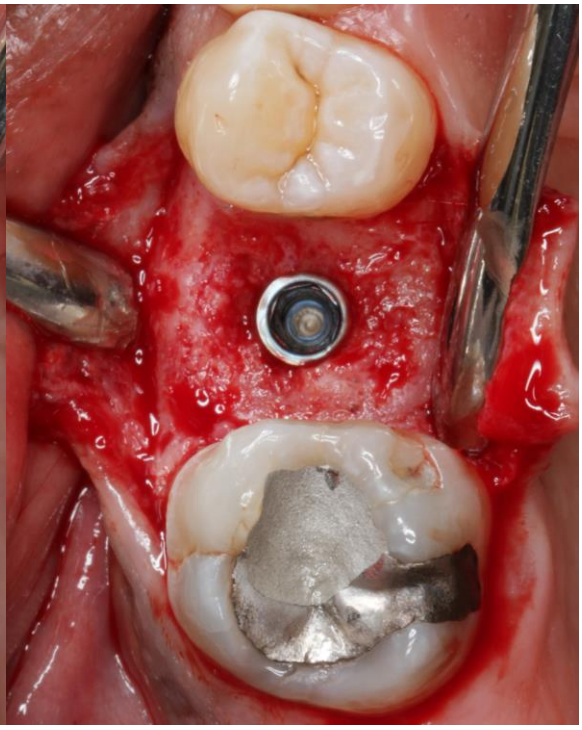
Laser generated blood clot.

Two weeks after RPG.

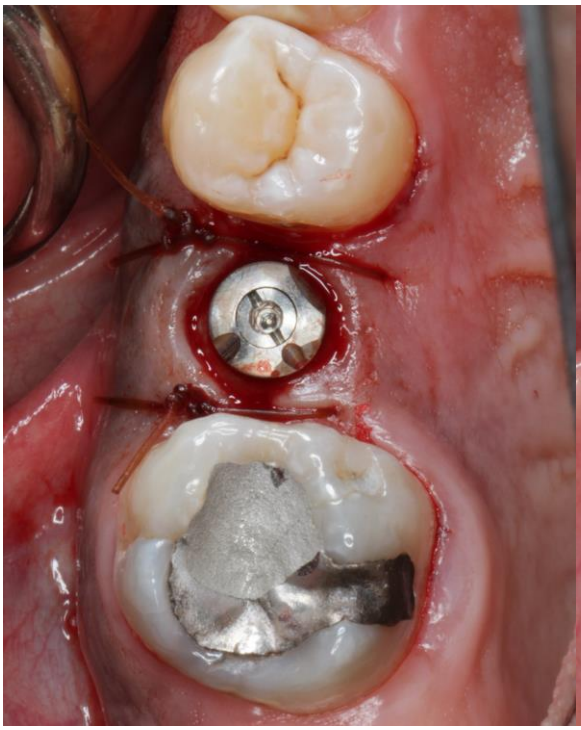
Ten weeks after RPG.



Flap reflected.

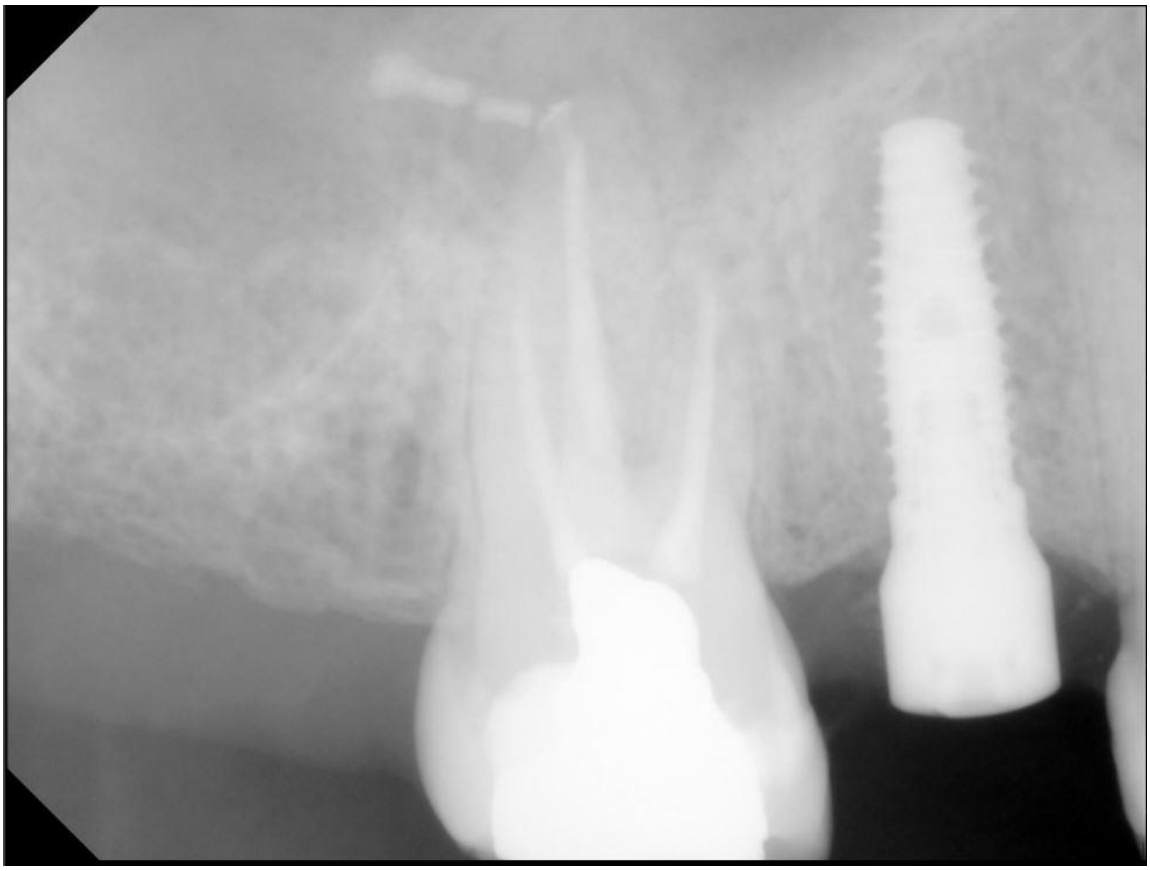


Implant placed.



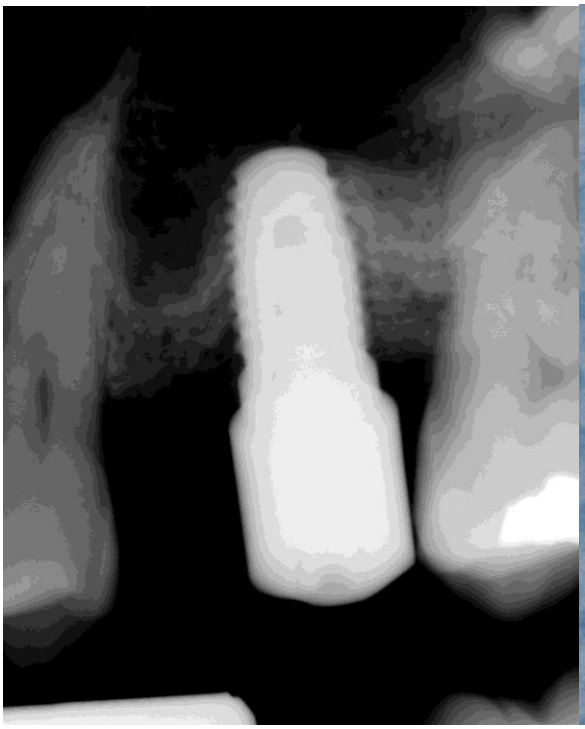
Healing abutment placed.

Two weeks after Implant.



Radiograph at implant surgery.

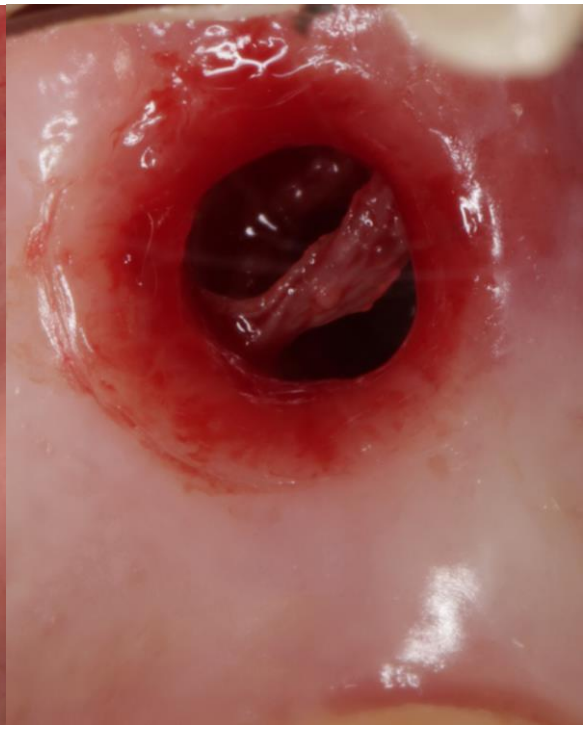
Case 6. Surgeon: CPT Dane Swenson **Date:** 9/18/2017
Diagnosis: Failed implant #14 (history of transalveolar sinus elevation at the site).



Peri-implant radiolucency.

Explanted fixture.

Residual alveolar defect.



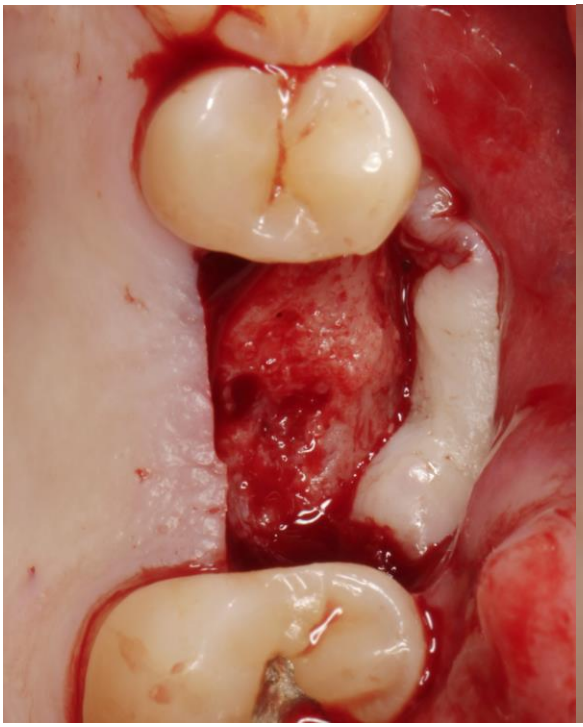
Detached fibrous encapsulation tissue.

FDBA placed.

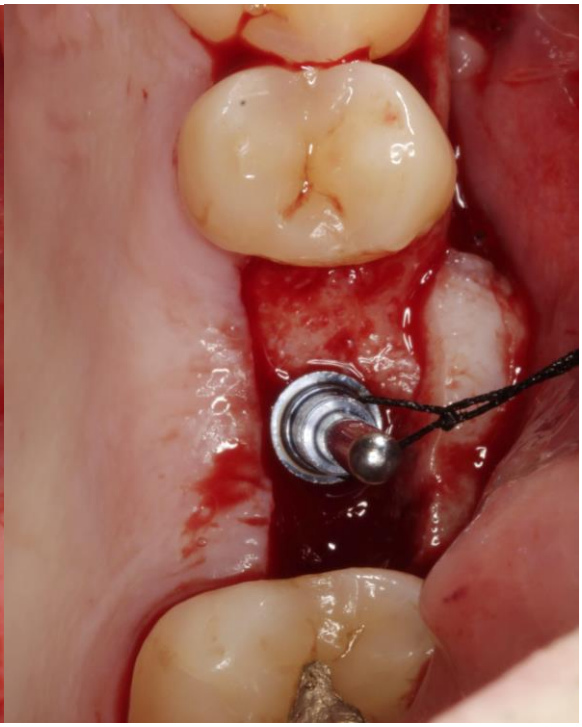
Laser generated blood clot.

One week after RPG.

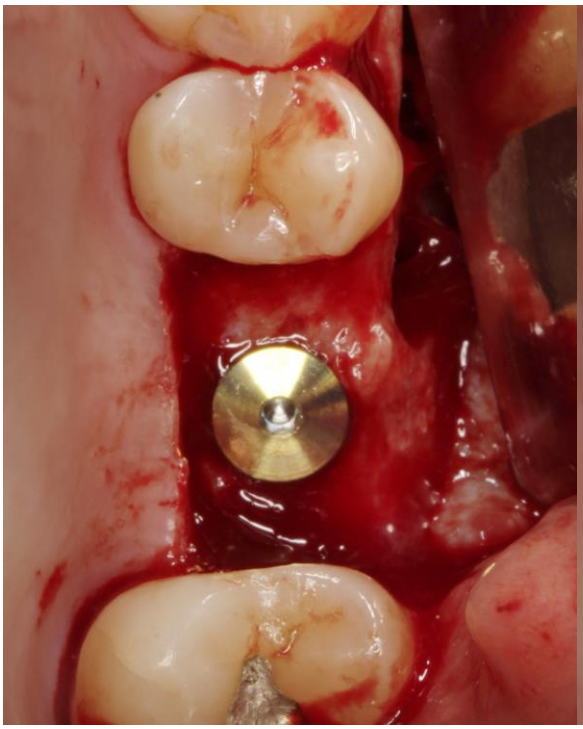
Two weeks after RPG.



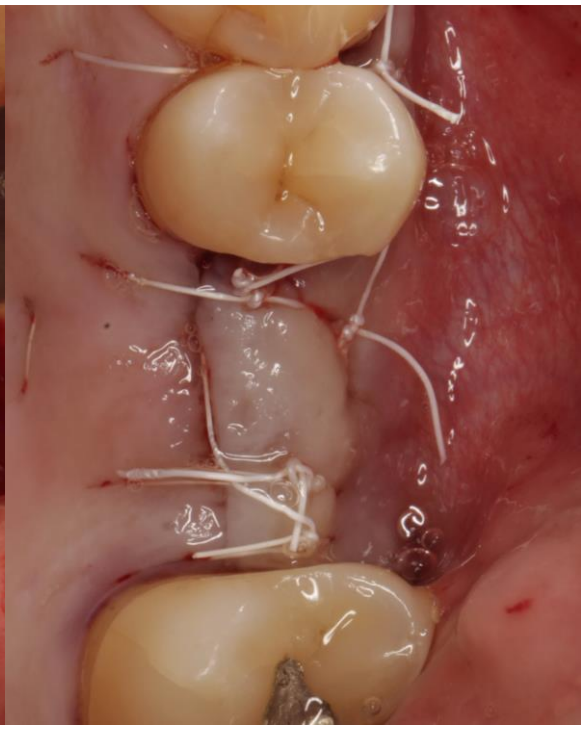
Four months after RPG.



Direction indicator placed.



Implant placed.

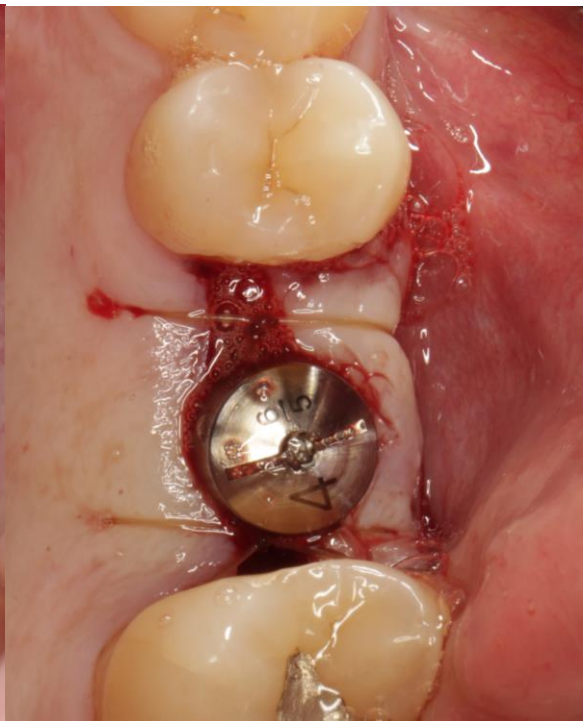


Closure.

One week after implant placement.

Two weeks after implant placement.

Five months after implant placement.

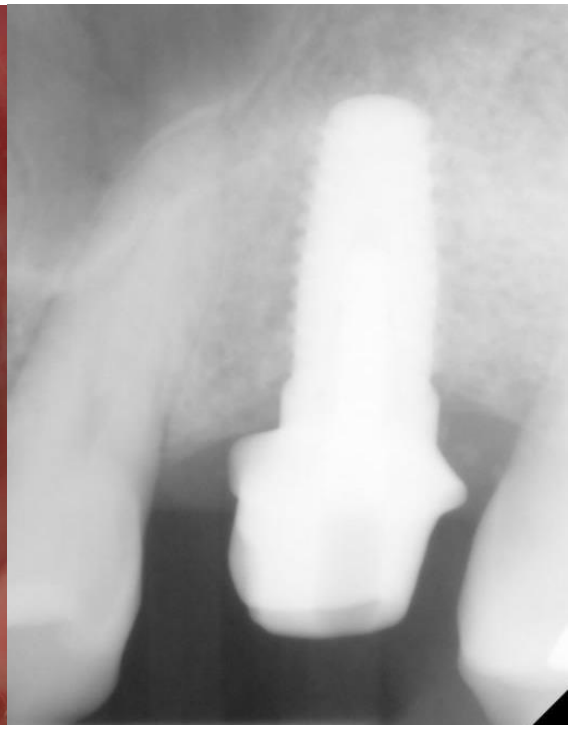


PhII.

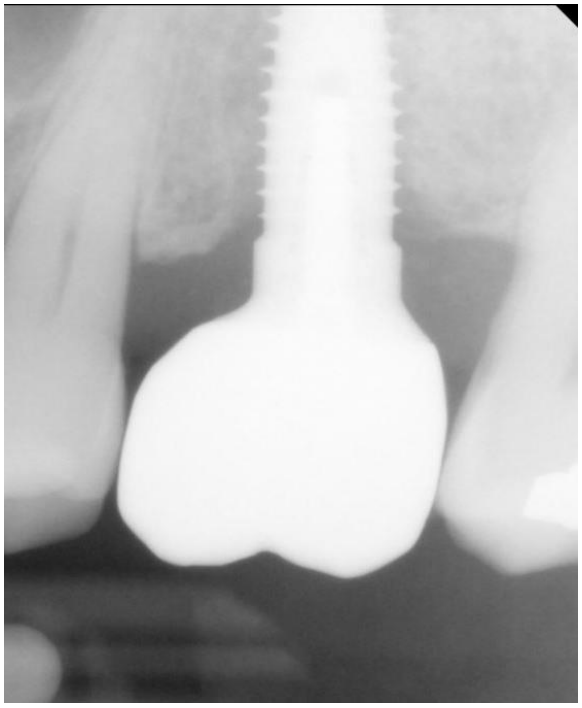
Five weeks after PhII.

Implant abutment nine weeks after PhII.

Final restoration by CPT Kellie O'Keefe, Department of Prosthodontics.

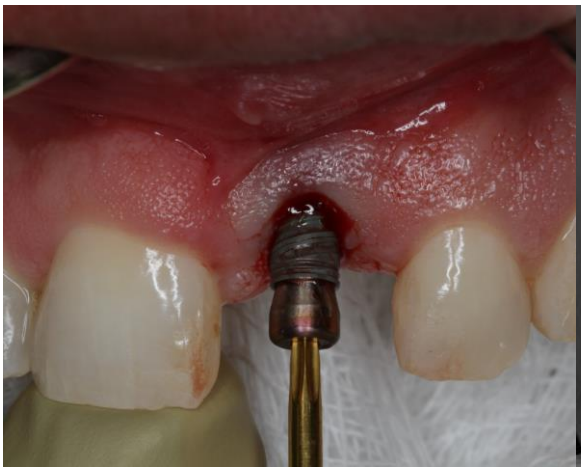


Radiograph with implant abutment.

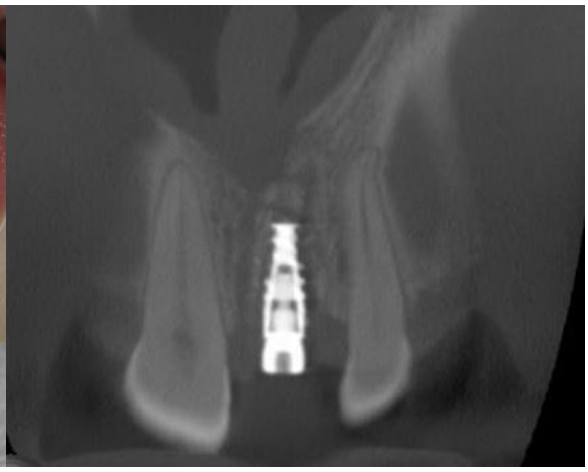


Radiograph following final restoration.

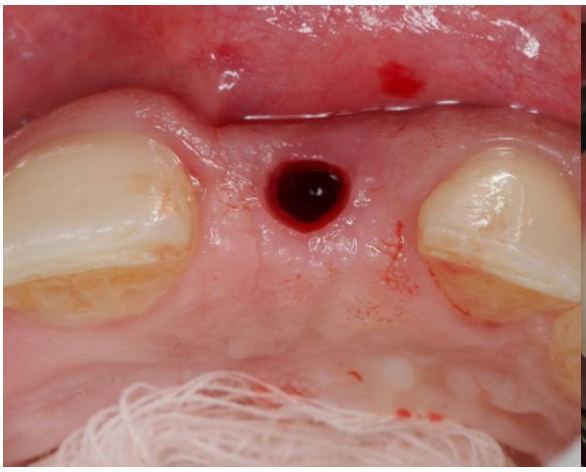
Case 7. Surgeon: MAJ Alicia Choi **Date:** 11/13/2018
Diagnosis: Failed implant #9



Failed implant explanted.



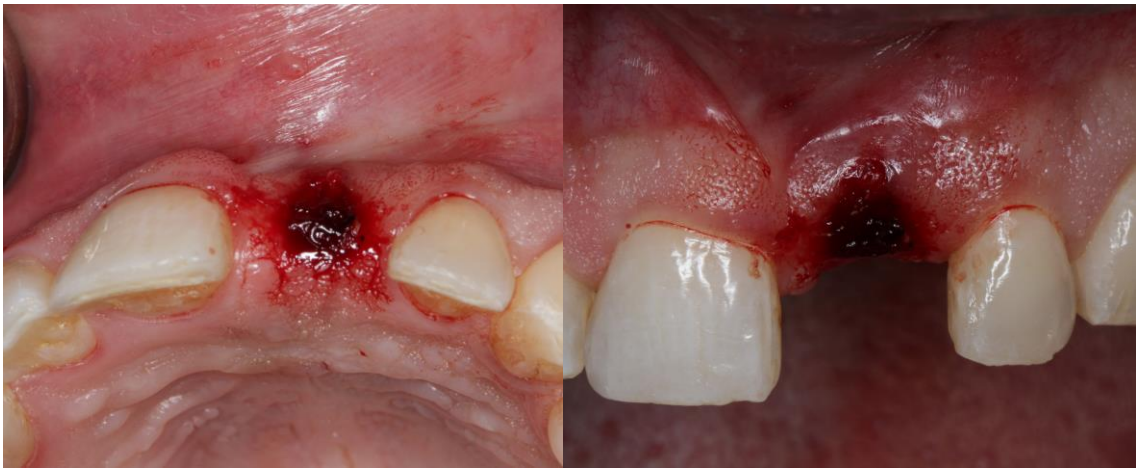
CBCT demonstrating zone of low density surrounding the implant.



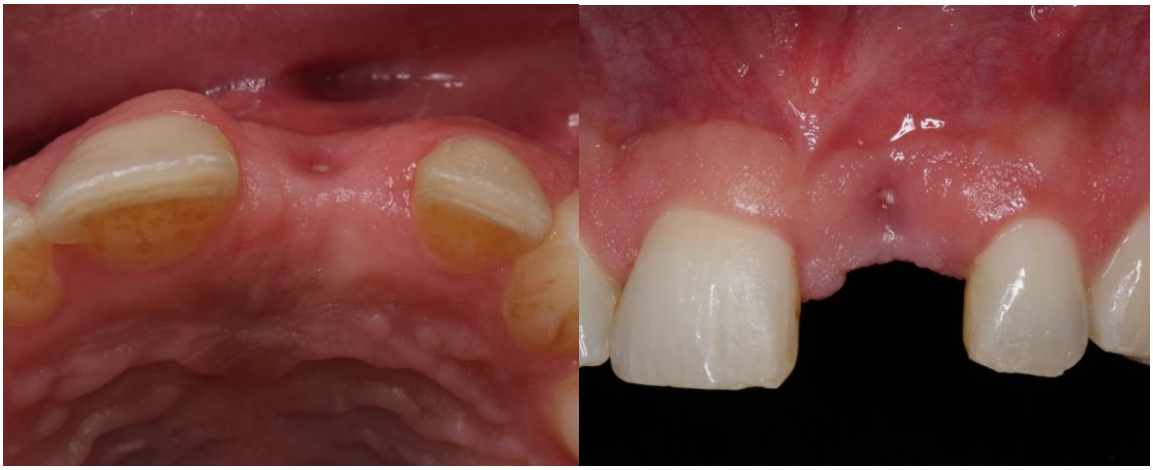
Post explant in occlusal view.

Post explant buccal view.

FDBA placed.



Laser generated blood clot.



Four weeks after RPG.

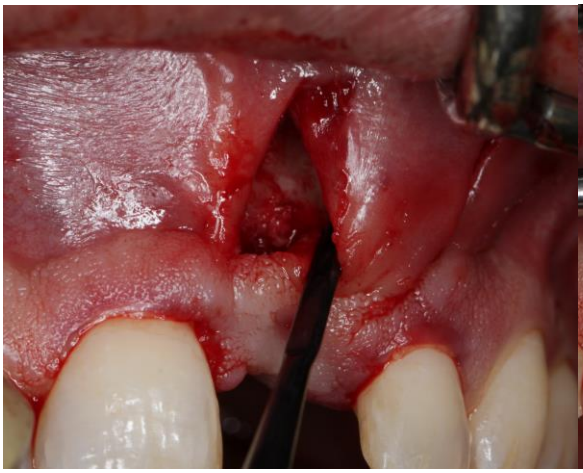
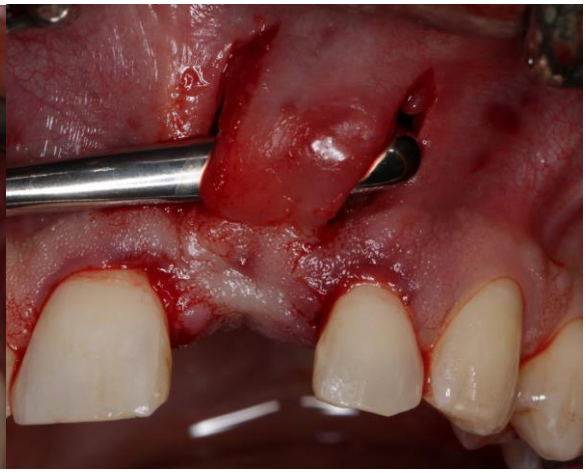
Nine weeks after RPG, residual FDBA was removed.

Laser generated blood clot following FDBA particle removal.

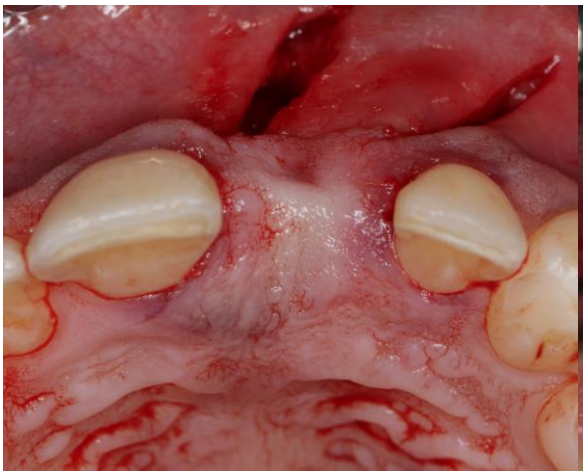
Four months after laser therapy.

GBR performed. Vestibular incisions.

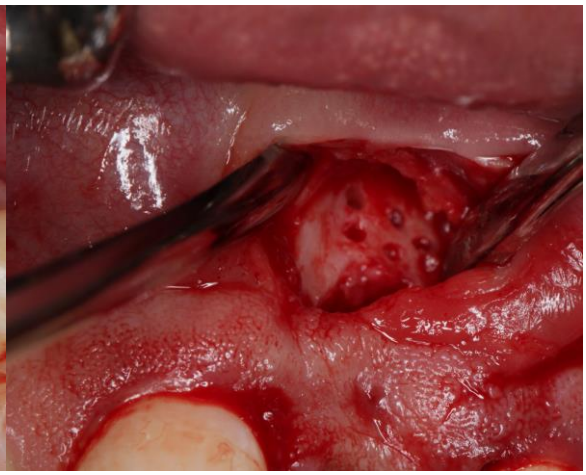
Tunnel access for GBR.

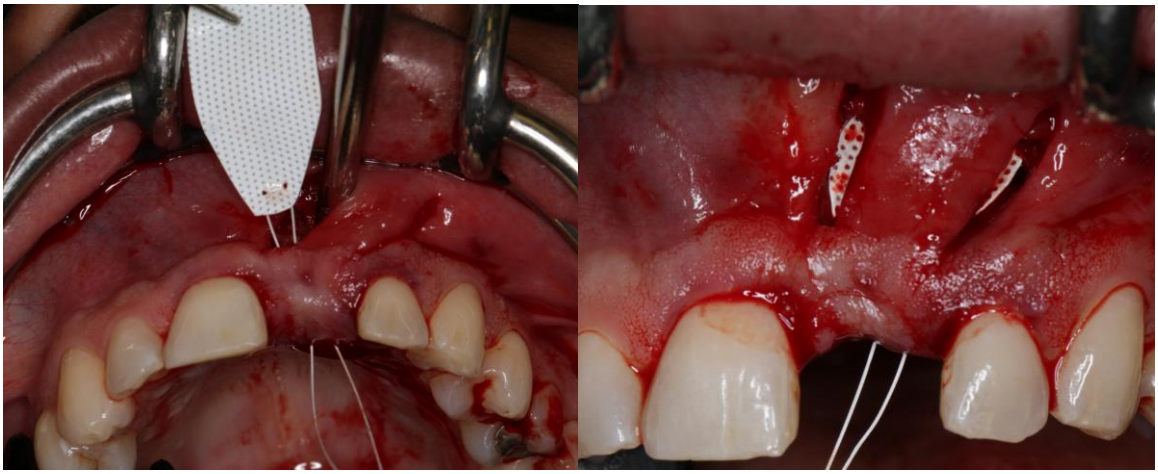
Flap reflection complete.



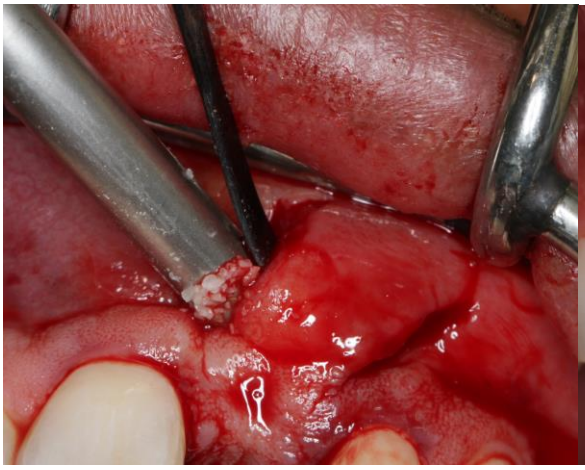
Ridge prior to augmentation.



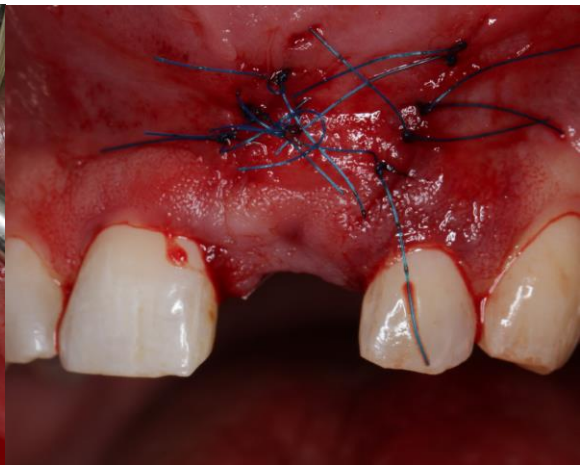
Decortication of alveolar bone.



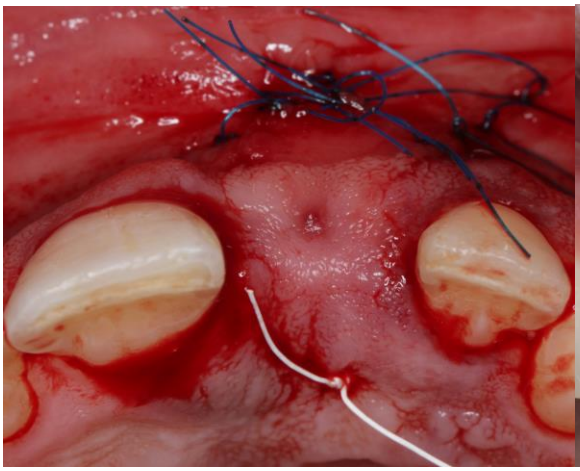
Dense polytetrafluoroethylene membrane trimmed and advanced over the alveolar crest.



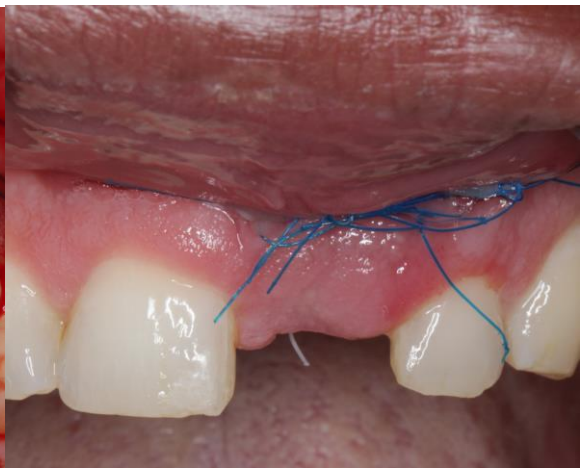
Bone carrier used to pack FDBA.



Polypropylene sutures applied.



Wound closure.



One week after GBR.

Two weeks after GBR, facial view.

Occlusal view.

Four weeks after GBR, facial view.

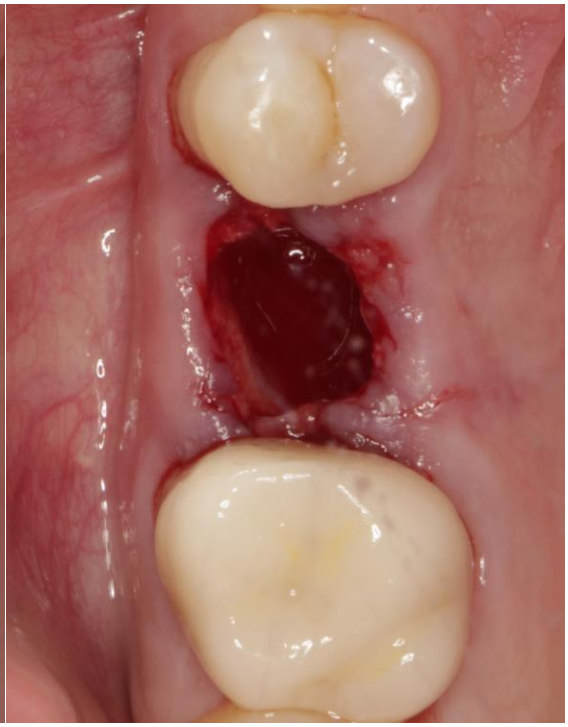
Occlusal view

Eight weeks after GBR, facial view.

Occlusal view.

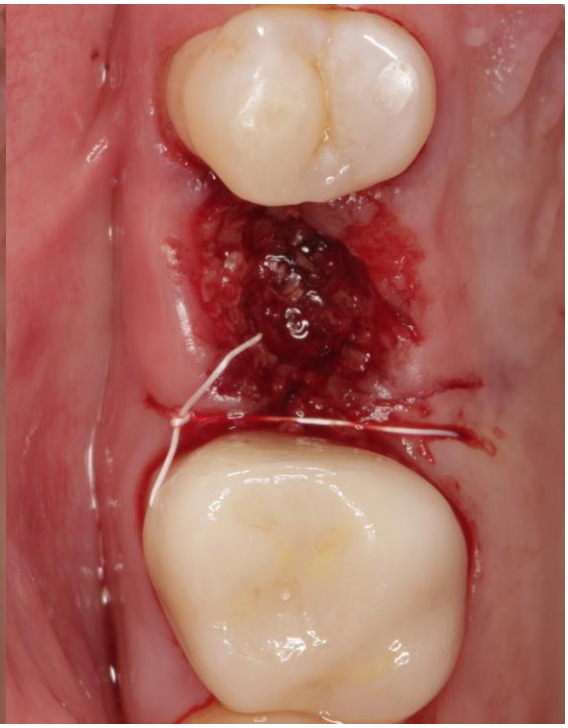
Case 8. Surgeon: CPT Daniel Phillips **Date:** 10/24/2018
Diagnosis: Nonrestorable tooth #4 (fracture, inadequate tooth structure)

Baseline.



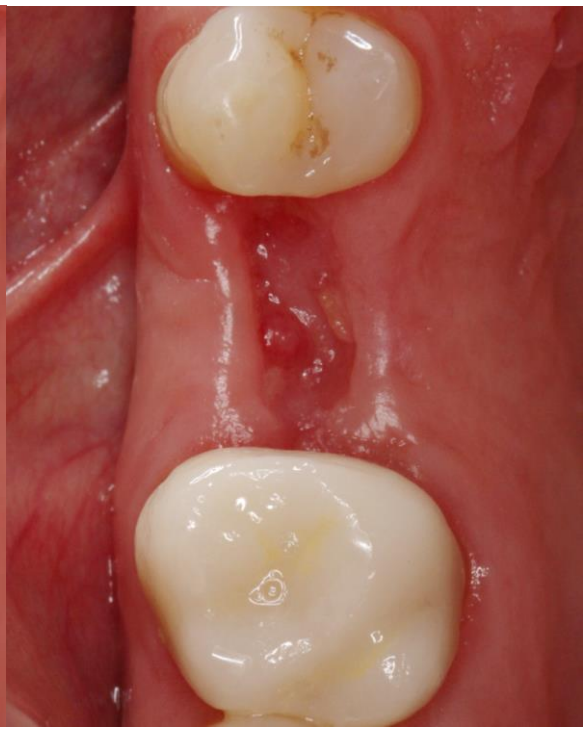
Minimally traumatic extraction.

FDBA placed.

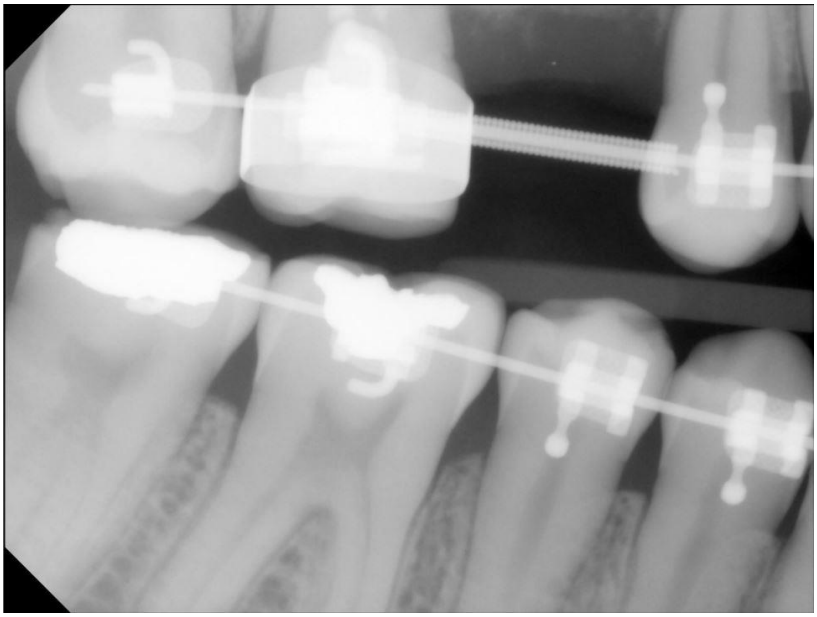


Laser generated blood clot.

Three weeks after RPG.



Six weeks after RPG.

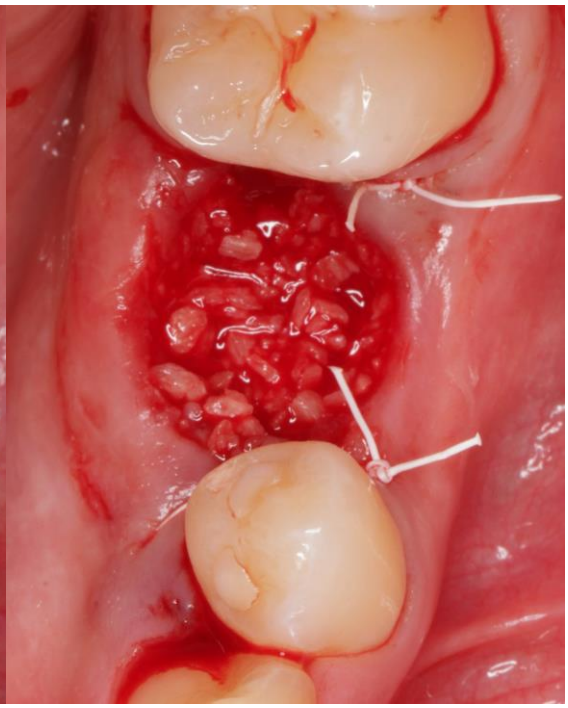


Bite wing radiograph six months following RPG.

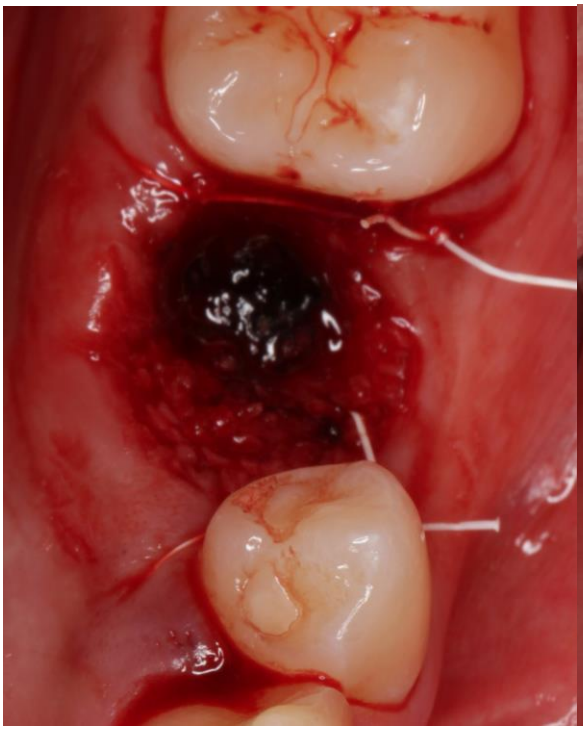
This patient is currently in orthodontic therapy prior to the implant phase.

Case 9. Surgeon: MAJ Alicia Choi **Date:** 1/16/2019
Diagnosis: Over-retained primary tooth #K (root resorption, ankylosis)

Baseline.



FDBA placed.



Laser generated blood clot.

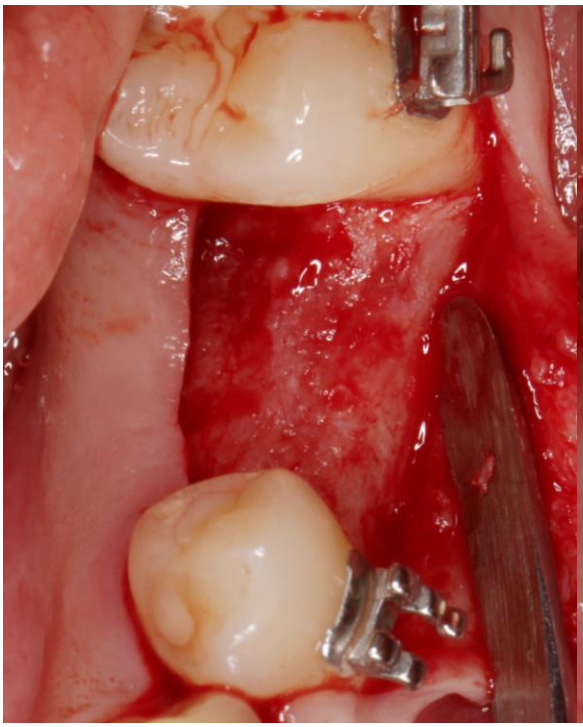
One week after RPG.

Three weeks after RPG.

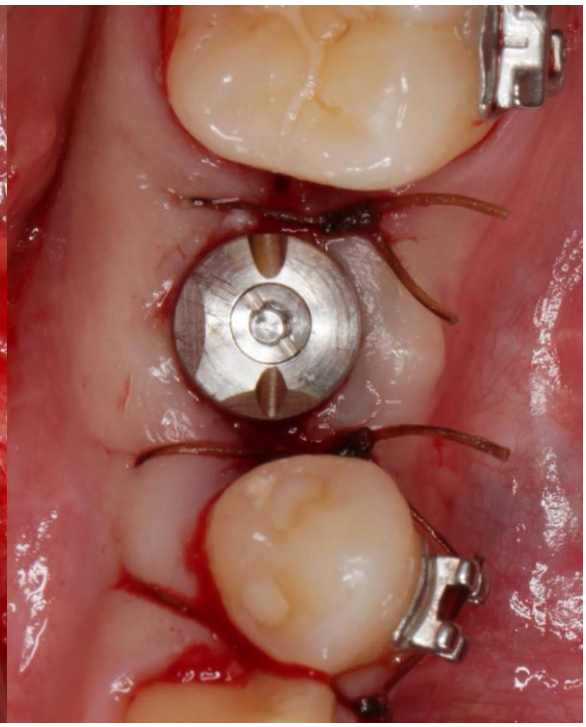
Five weeks after RPG.

Four months after RPG.

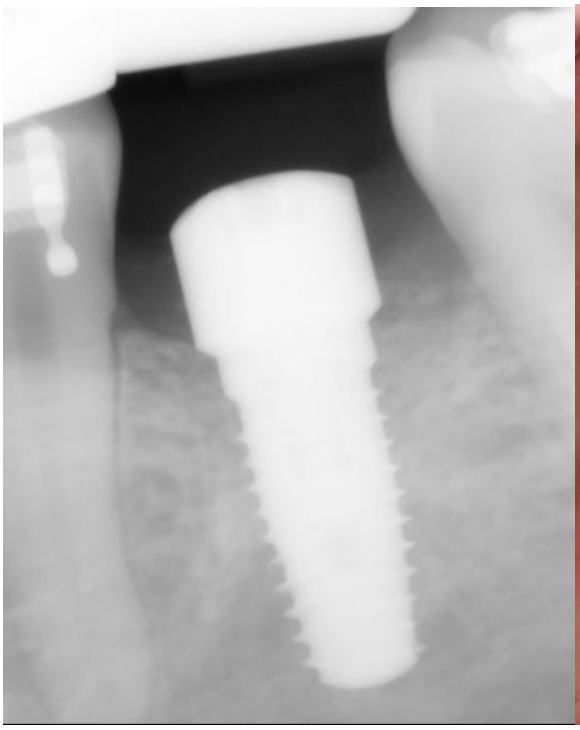
Six months after RPG.



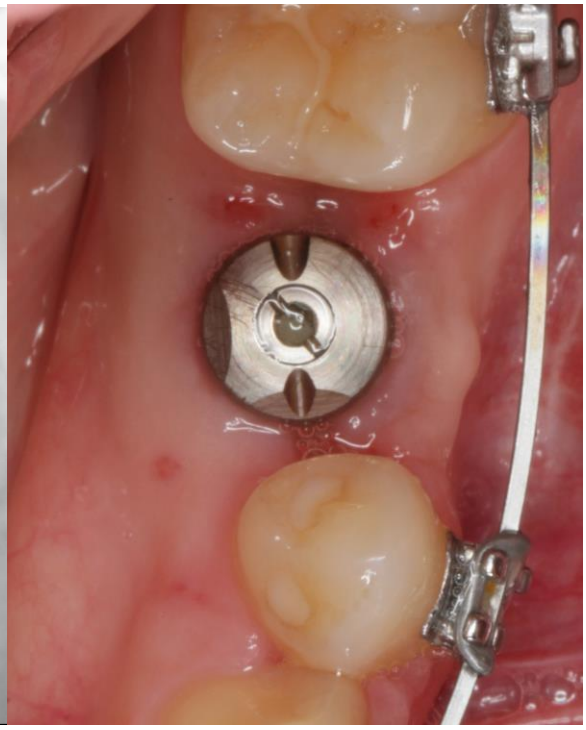
Flap reflected.



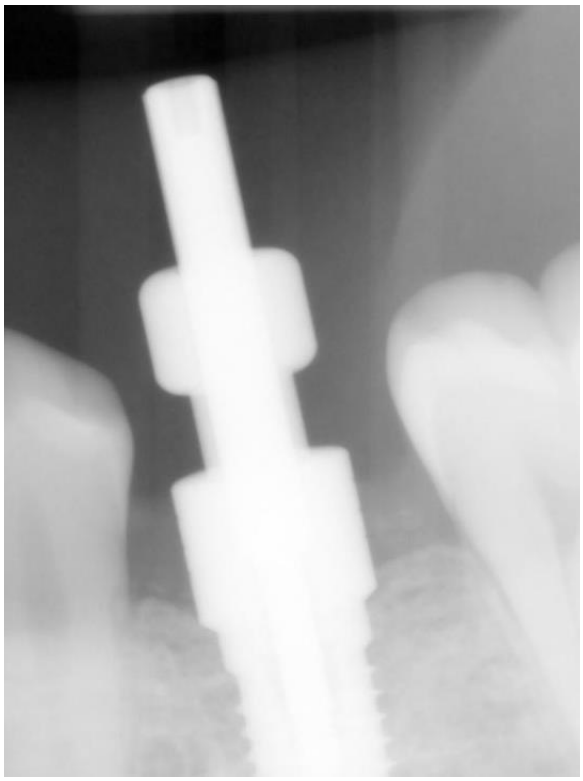
Implant and healing abutment placed.



Radiograph at implant surgery.



Two weeks after implant placement.

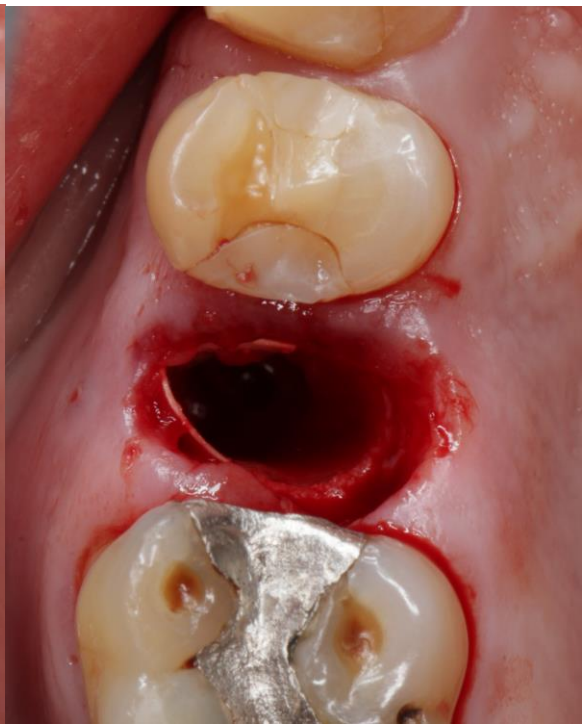


Radiograph of impression coping.

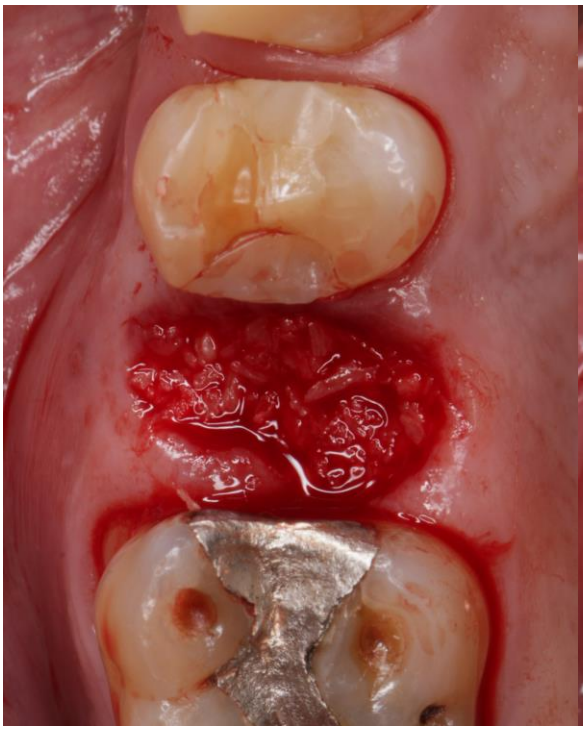
MAJ Jordan Bell, Department of Prosthodontics, Army Postgraduate Dental School is currently treating this patient.

Case 10. Surgeon: MAJ Alicia Choi **Date:** 2/25/2019
Diagnosis: Nonrestorable tooth #4 (caries, inadequate tooth structure, periodontitis)

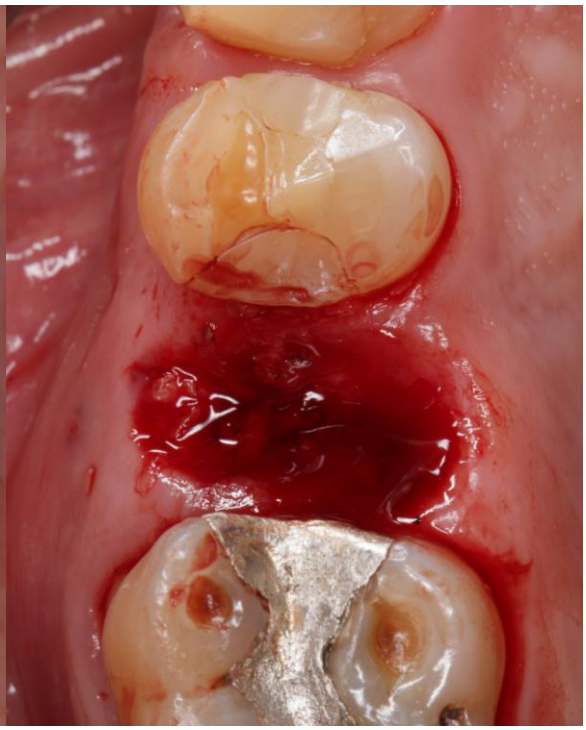
Baseline.



Elian class 2 socket. Collagen membrane used to recreate the buccal wall.



FDBA placed.



Laser generated blood clot.

One week after RPG.

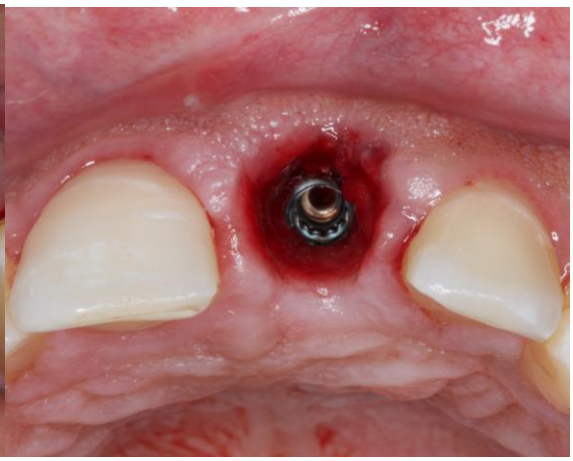
Two weeks after RPG.

Four weeks after RPG.

This patient departed Fort Gordon prior to implant surgery.

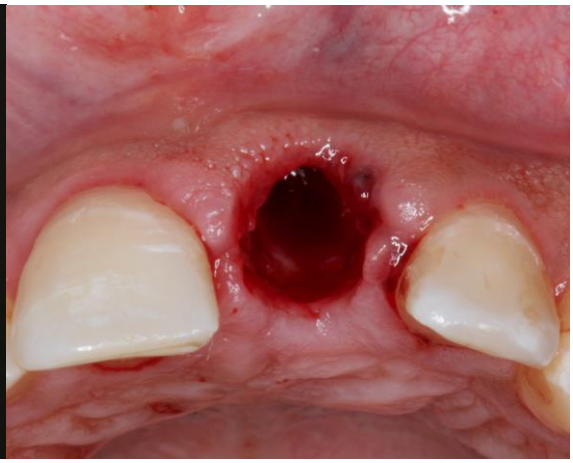
Case 11. Surgeon: MAJ Alicia Choi **Date:** 5/13/2019
Diagnosis: Failed immediate implant #9

Failed implant site, #9 position.

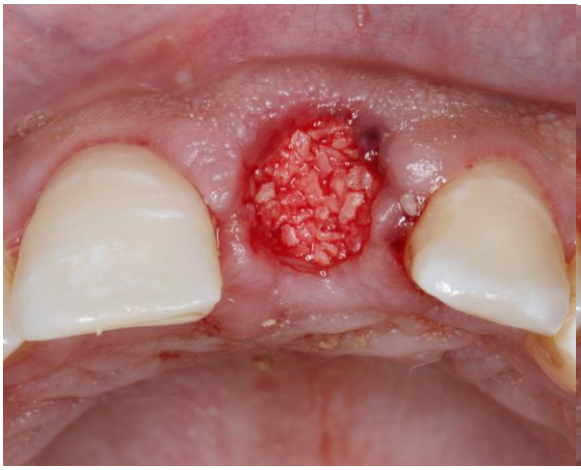


Provisional restoration removed.

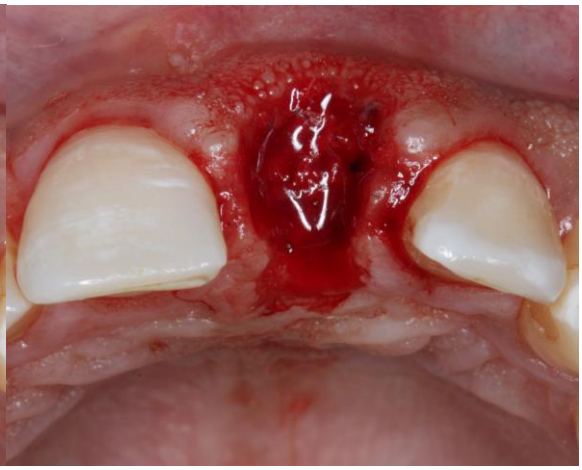
Implant explanted.



Residual alveolar defect.



FDBA placed.



Laser generated blood clot.

One week after RPG, occlusal view.

Facial view.

Two weeks after RPG, occlusal view.

Facial view.

Three weeks after RPG, occlusal view.

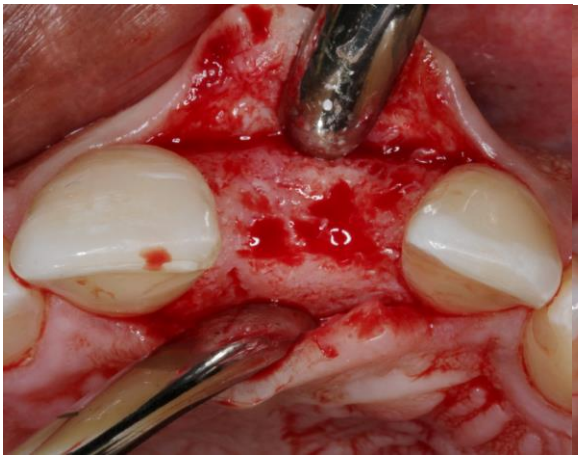
Facial view.

Three months after RPG, occlusal view.

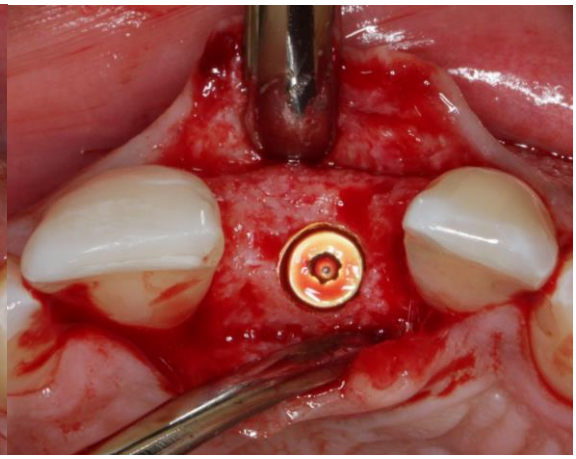
Facial view.

Four months after RPG, occlusal view.

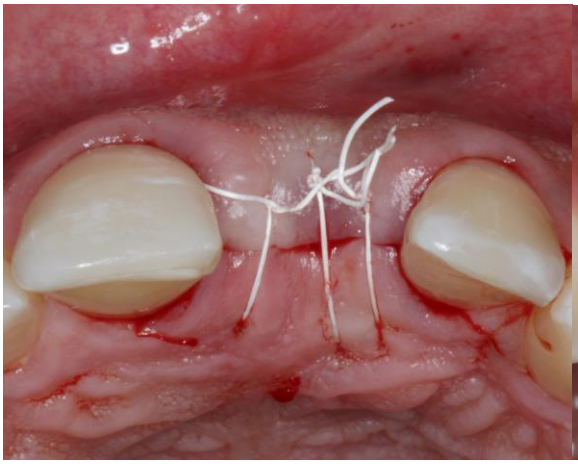
Facial view.



Flap reflected.



Implant placed.



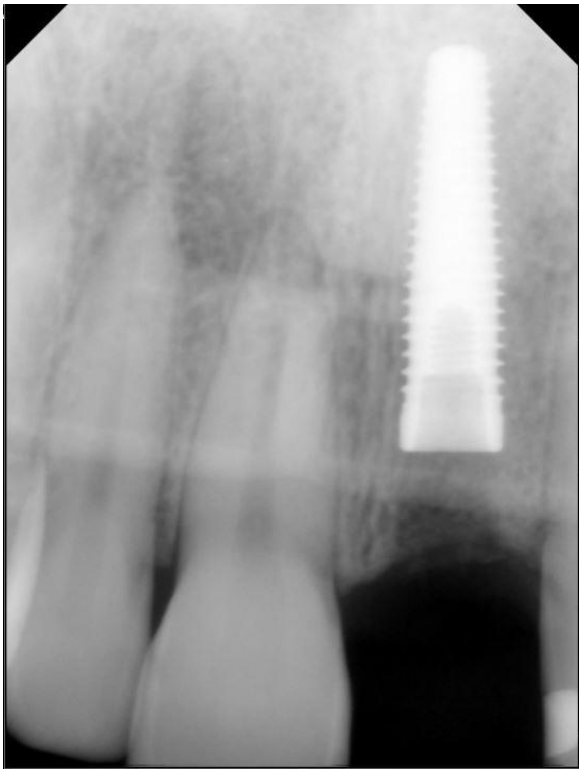
Wound closure, occlusal view.

Facial view.

One week after implant placement.

Sutures removed at postoperative week one.

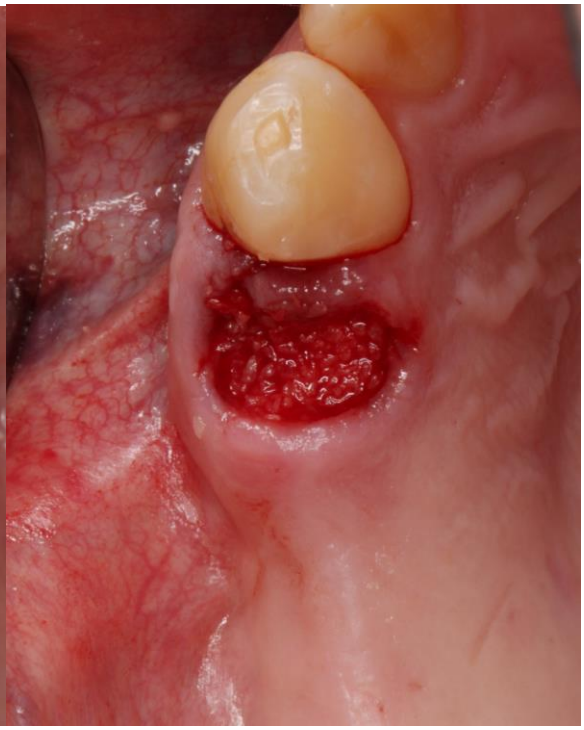
Five weeks after implant placement.



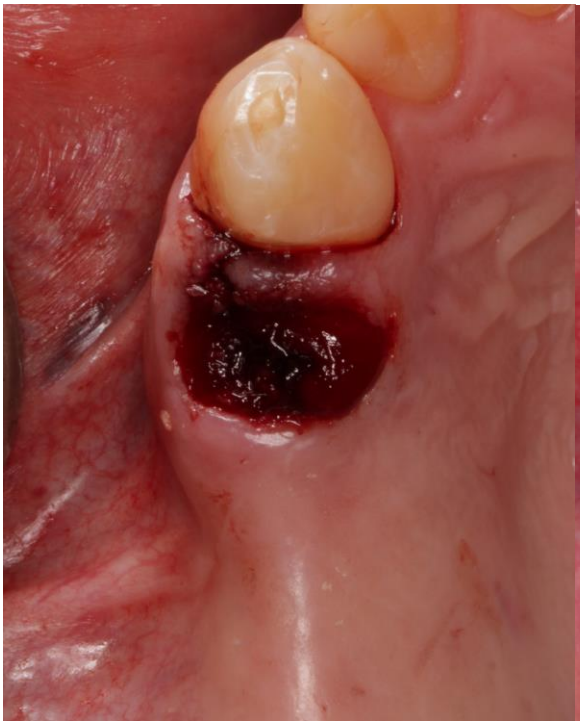
Radiograph at implant placement.

Case 12. Surgeon: MAJ Alicia Choi **Date:** 3/27/2019
Diagnosis: Nonrestorable tooth #5 (root caries)

Baseline.



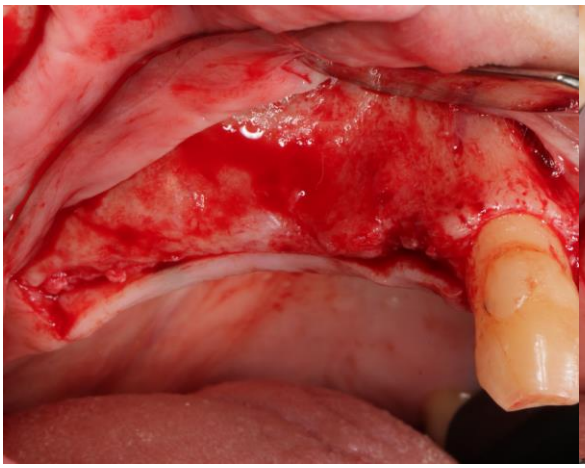
FDBA placed.



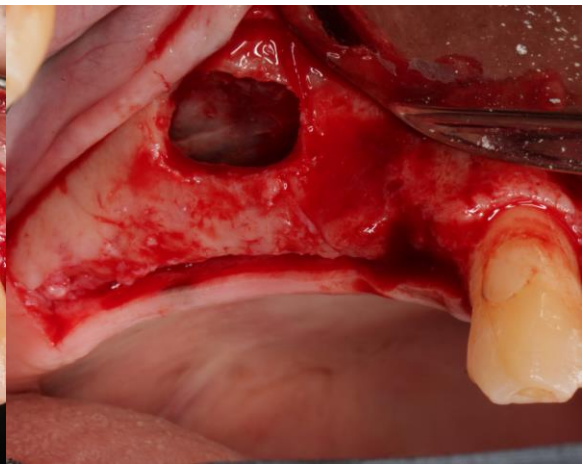
Laser generated blood clot.

Two weeks after RPG.

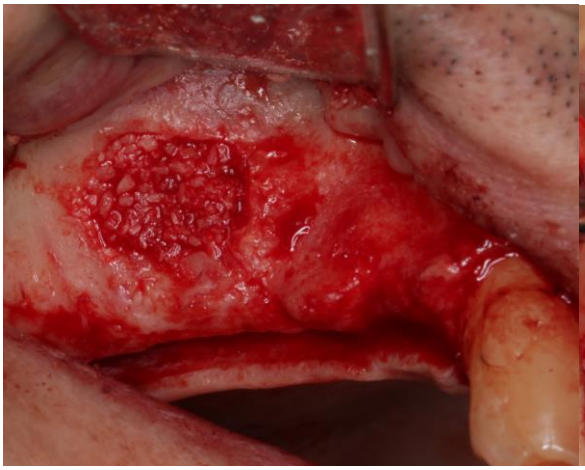
Three months after RPG.



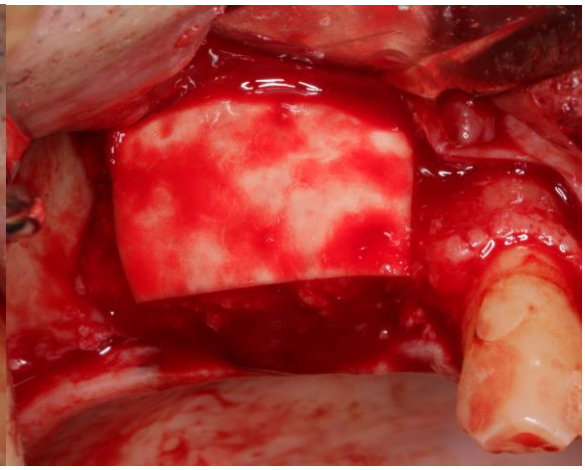
Lateral sinus elevation performed.



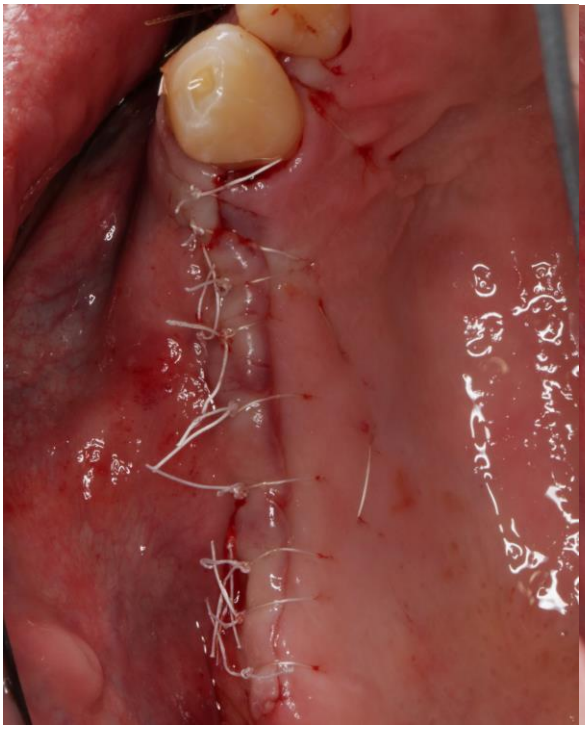
Lateral window opened, membrane elevated.



FDBA placed.



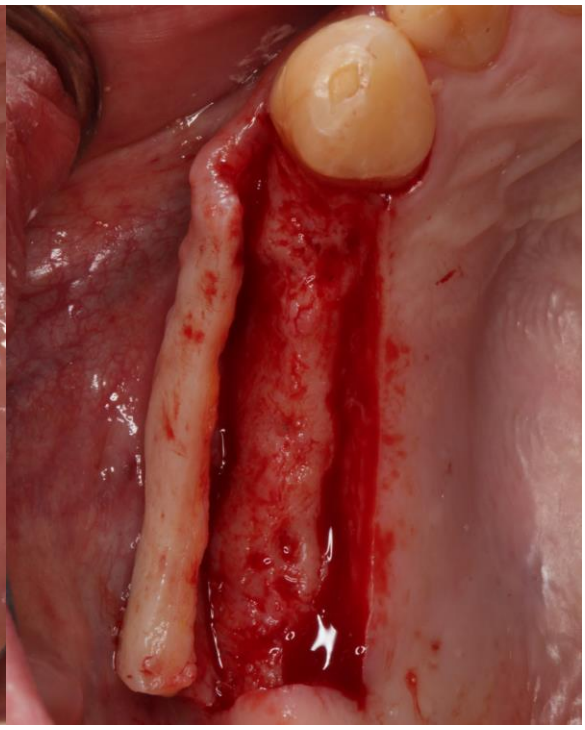
BioMend membrane placed.



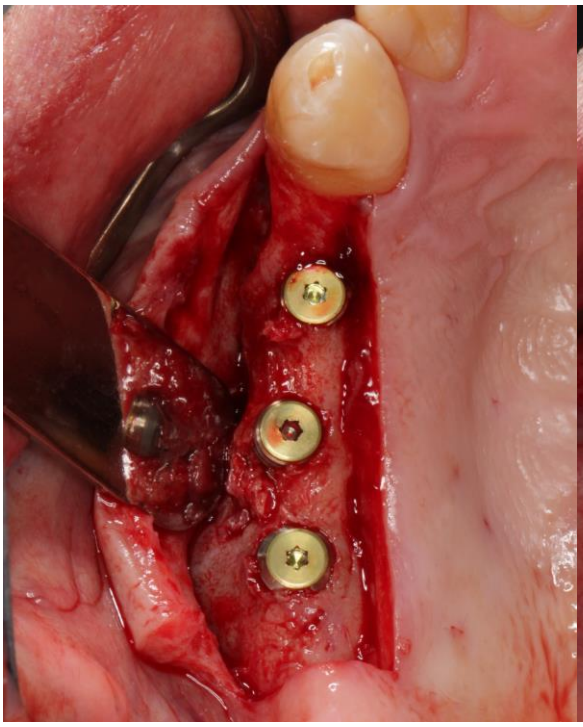
Wound closure.

Two weeks after sinus elevation.

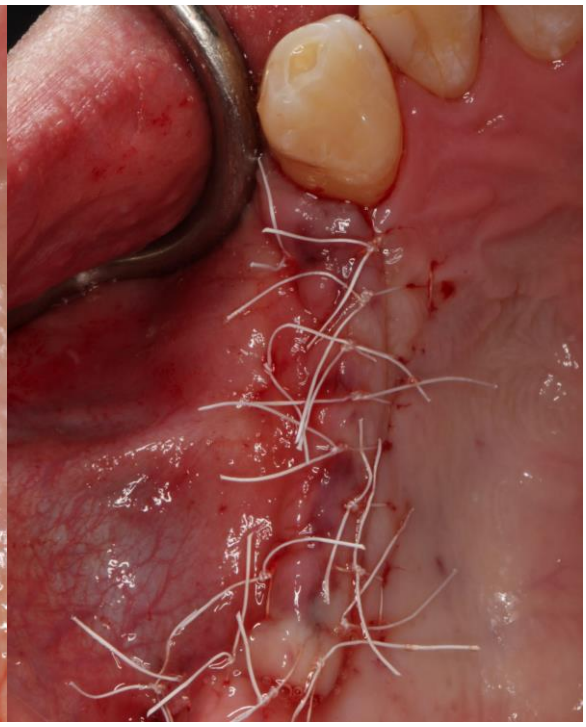
Six months after sinus elevation.



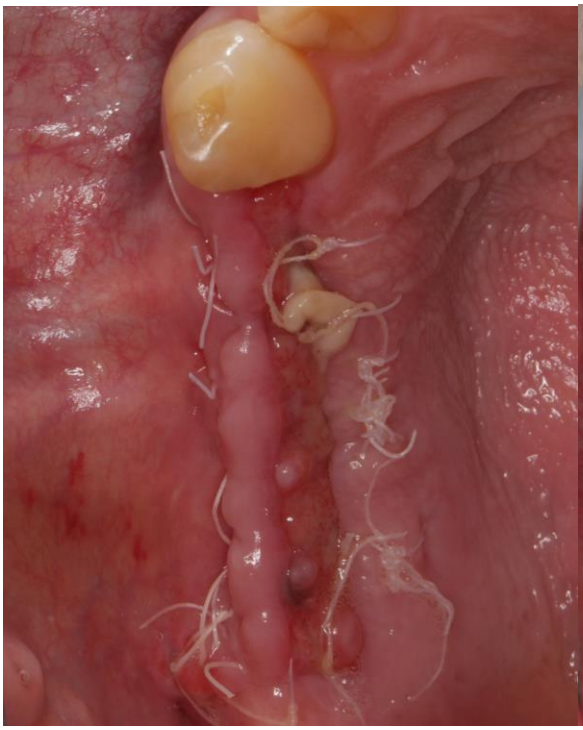
Flap reflected.



Implants #3, 4, 5 placed with overlay graft.

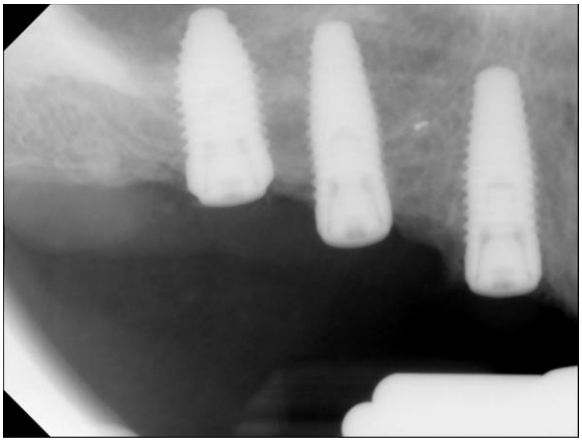


Wound closure.



One weeks after implant placement.

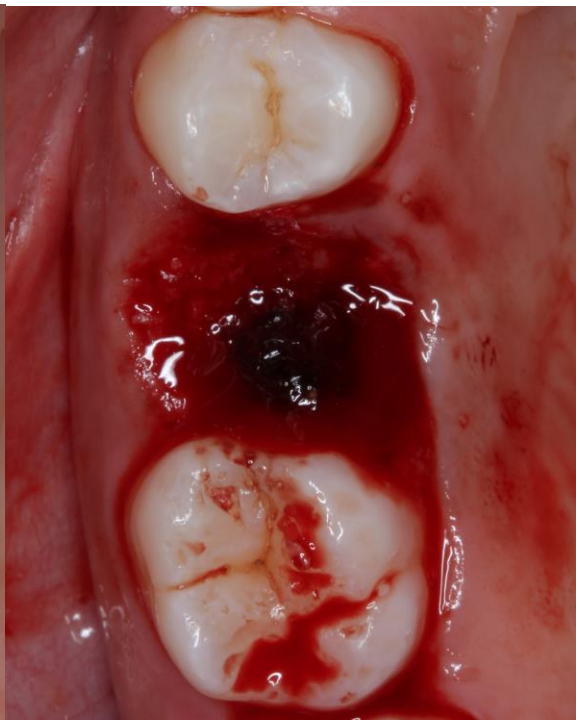
Two weeks after implant placement.



Radiograph at implant placement.

Case 13. Surgeon: CPT Ryan McGary **Date:** 2/6/2019
Diagnosis: Over-retained primary tooth #K with root resorption

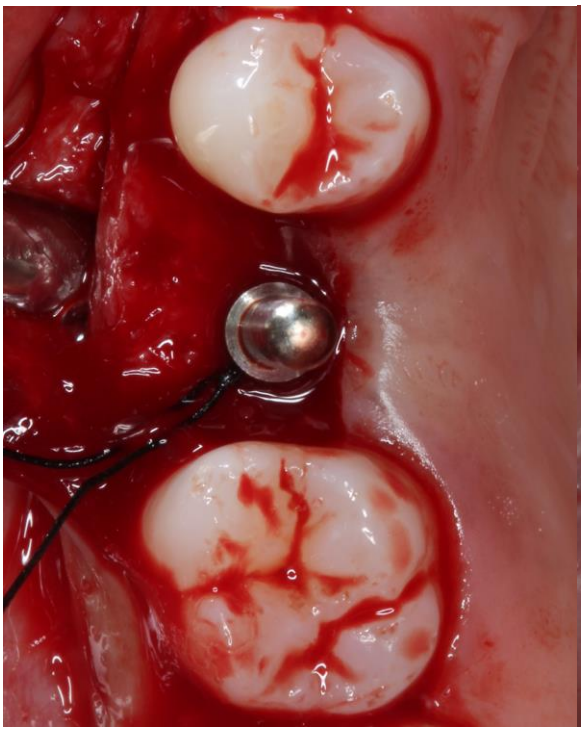
FDBA placed after extraction.



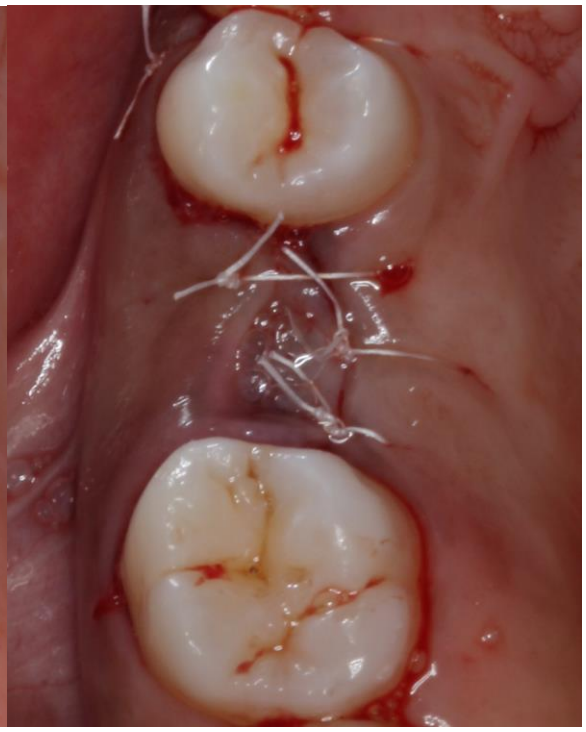
Laser generated blood clot.

Two weeks after RPG.

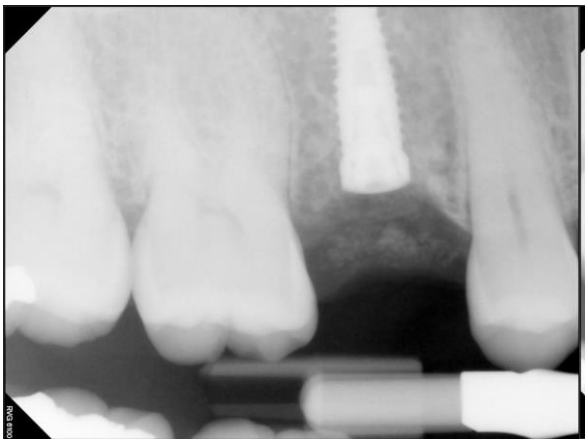
Five weeks after RPG.



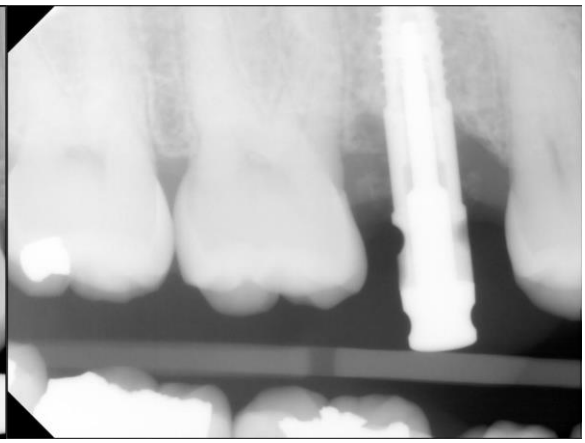
Three months after RPG, implant placed.



Wound closure.

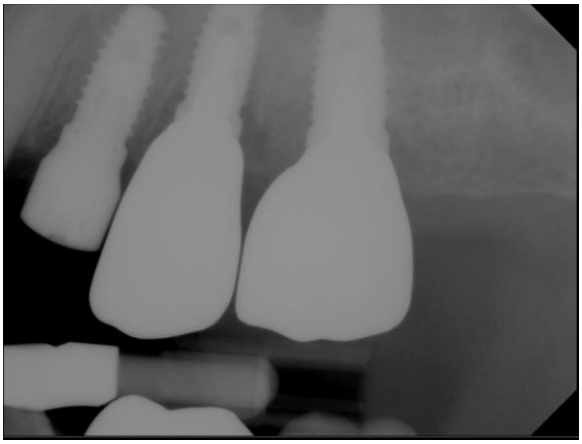


Radiograph at implant placement.



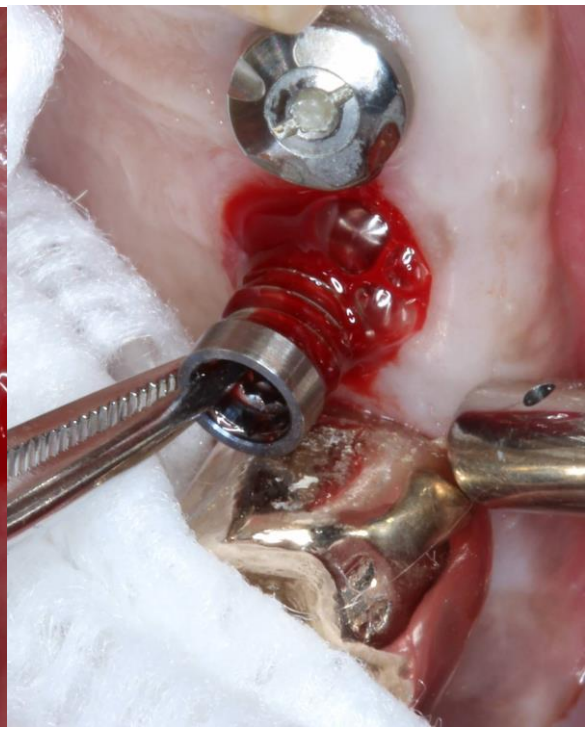
MAJ William Belknap restored the implant at Ft Lee.

Case 14. Surgeon: CPT Ryan McGary **Date:** 3/29/2019
Diagnosis: Failed implant #13



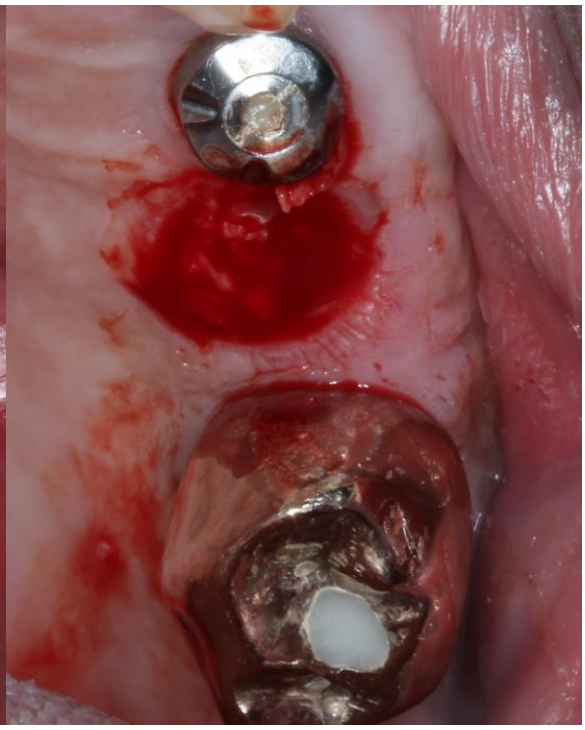
Peri-implant radiolucency, #13 position.

Failed implant #13.

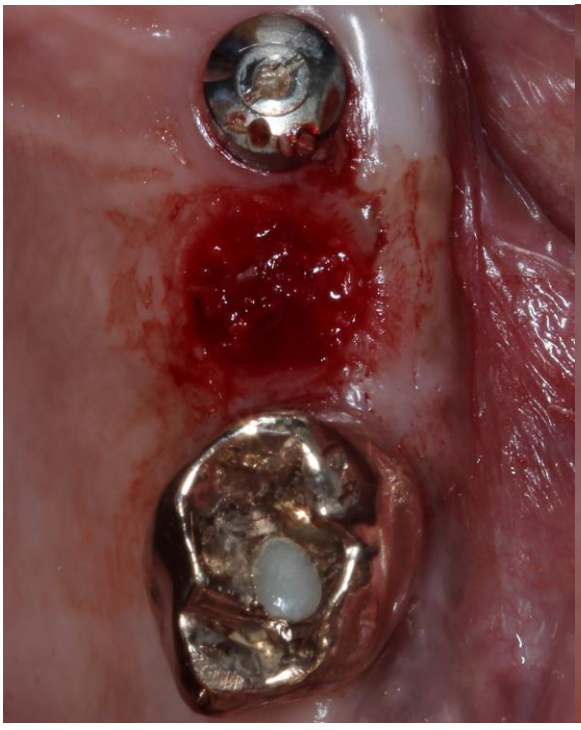


Implant explanted.

Site after implant removal.

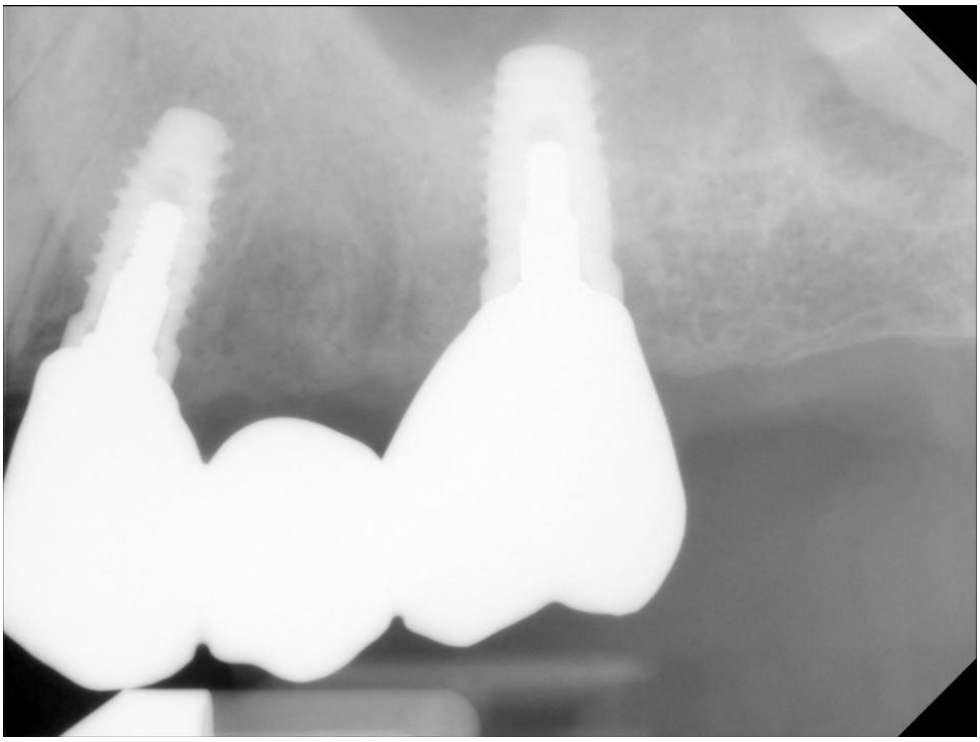


FDBA placed.



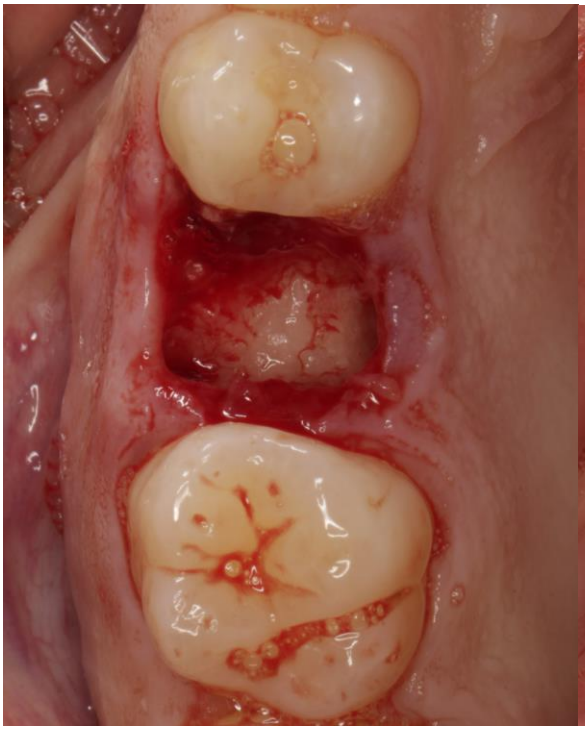
Laser generated blood clot.

Two weeks after RPG.

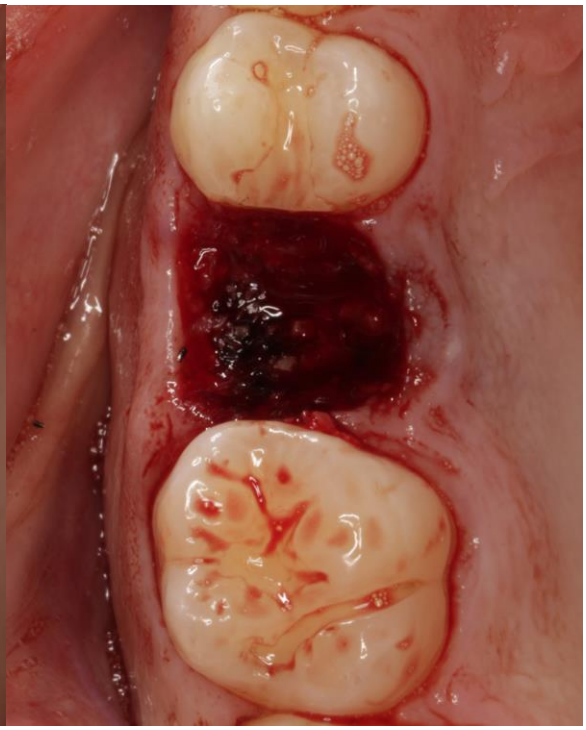


Final implant supported fixed partial denture delivered by CPT Ryan Coello.

Case 15. Surgeon: CPT Dane Swenson **Date:** 1/9/2019
Diagnosis: Over-retained primary tooth #A with root resorption



Minimally traumatic extraction.

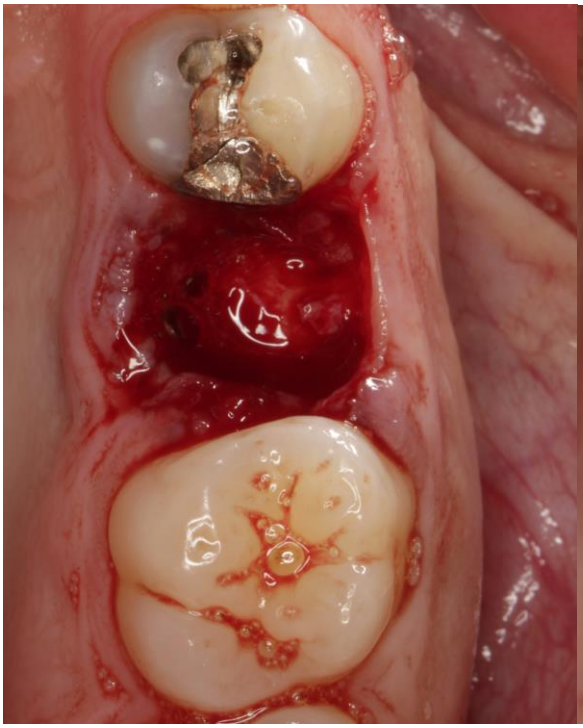


Laser generated blood clot.

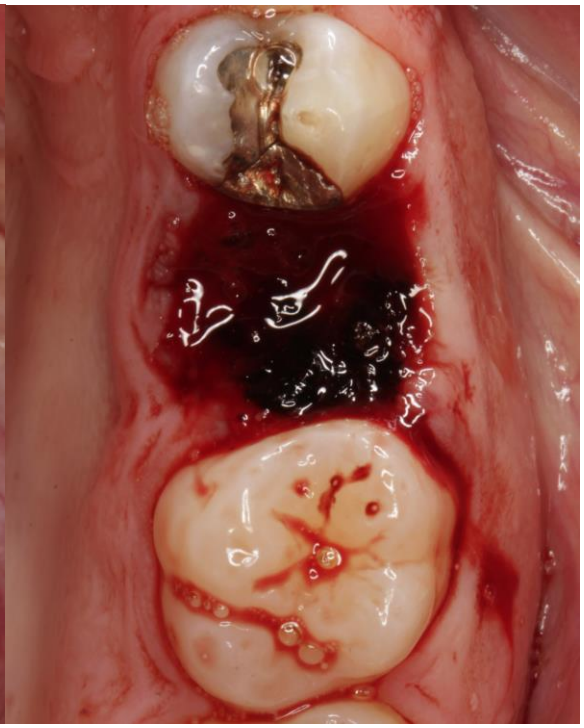
One week after RPG.

Eight weeks after RPG.

Case 16. Surgeon: CPT Dane Swenson **Date:** 1/9/2019
Diagnosis: Over-retained primary tooth #J with root resorption and periodontitis



Minimally traumatic extraction.



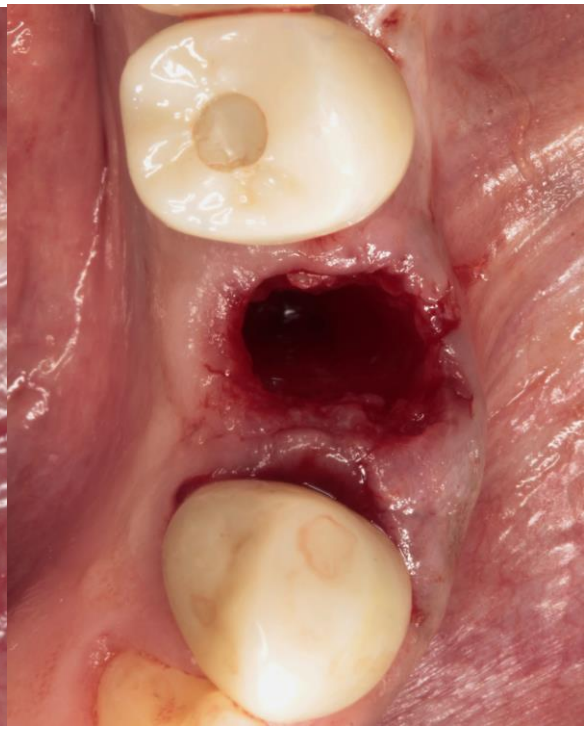
Laser generated blood clot.

One week after RPG.

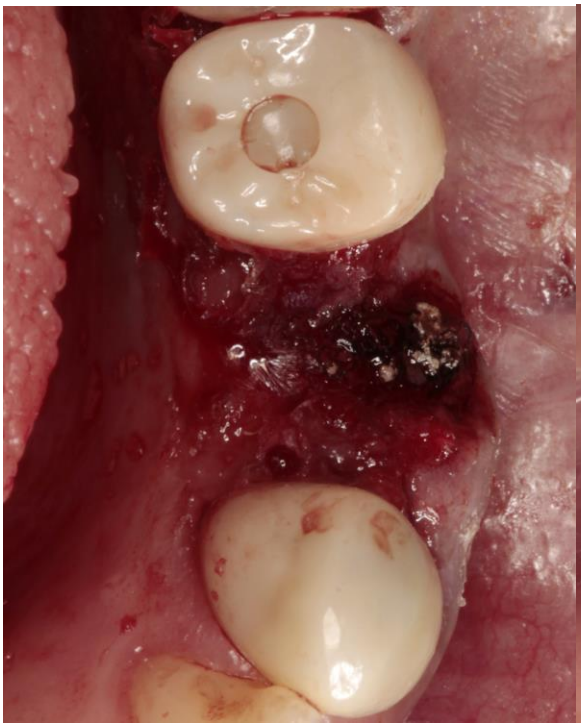
Eight weeks after RPG.

Case 17. Surgeon: CPT James Wilson **Date:** 5/20/2019
Diagnosis: Nonrestorable #21 (root caries, insufficient tooth structure)

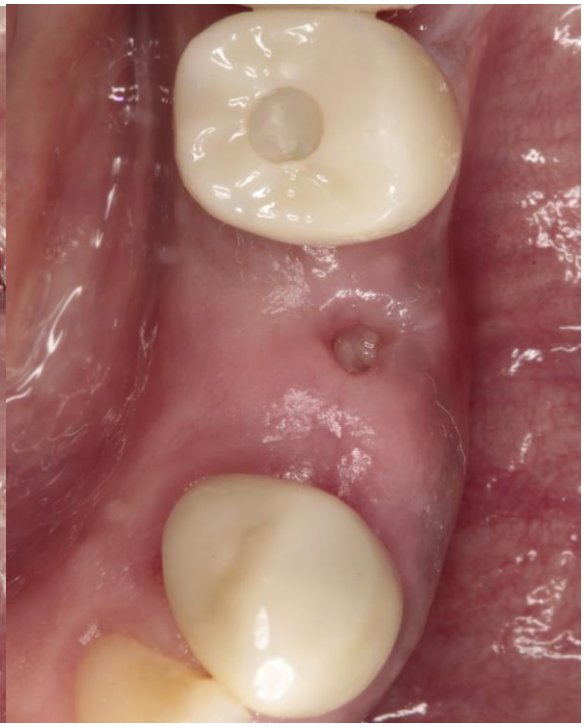
Baseline.



Minimally traumatic extraction.

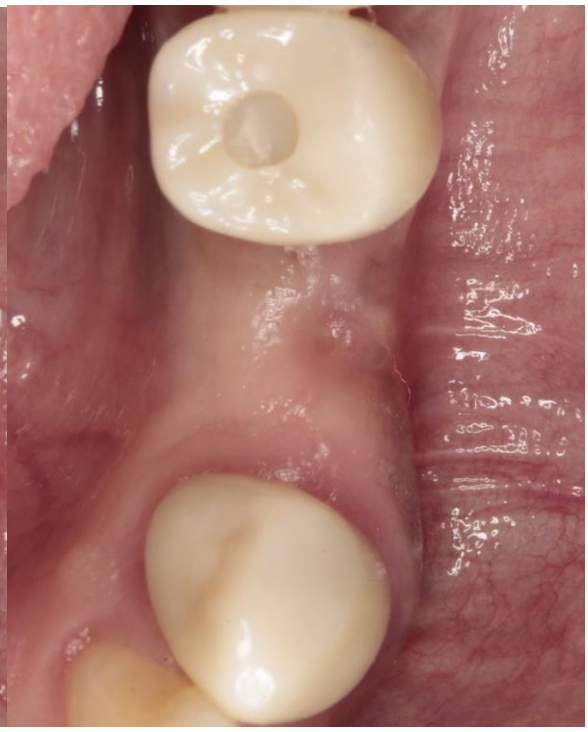


Laser generated blood clot.



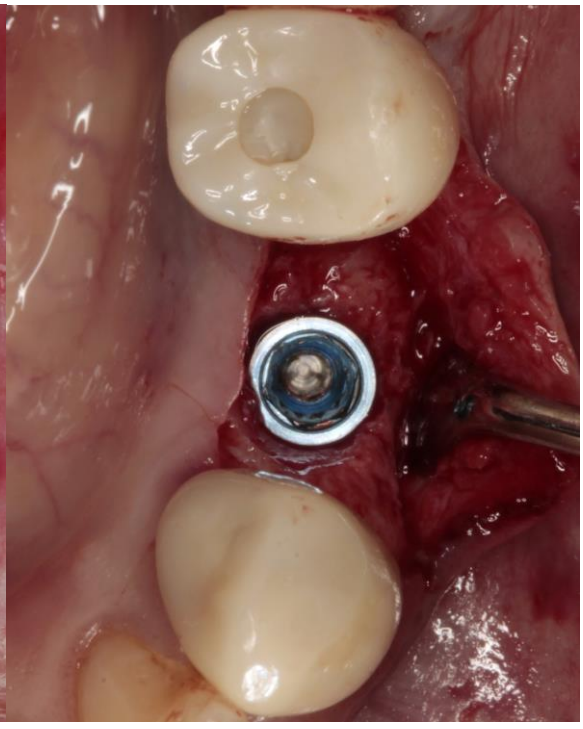
One week after RPG.

Three weeks after RPG.

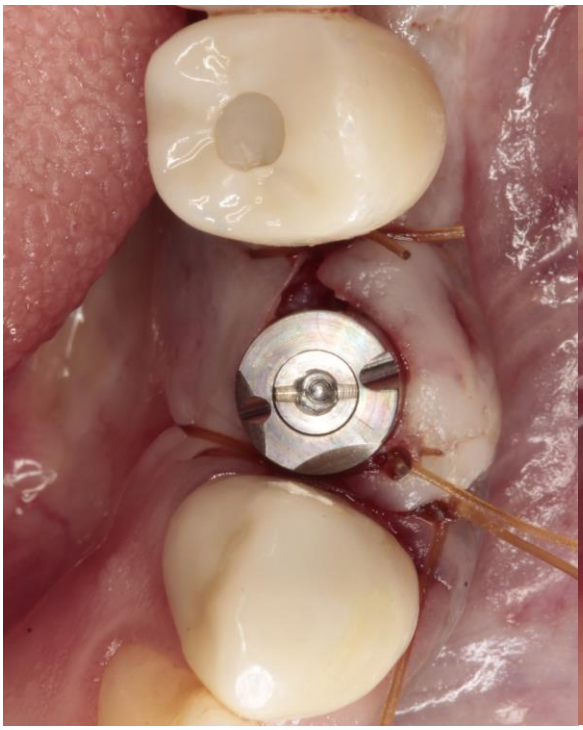


Five months after RPG.

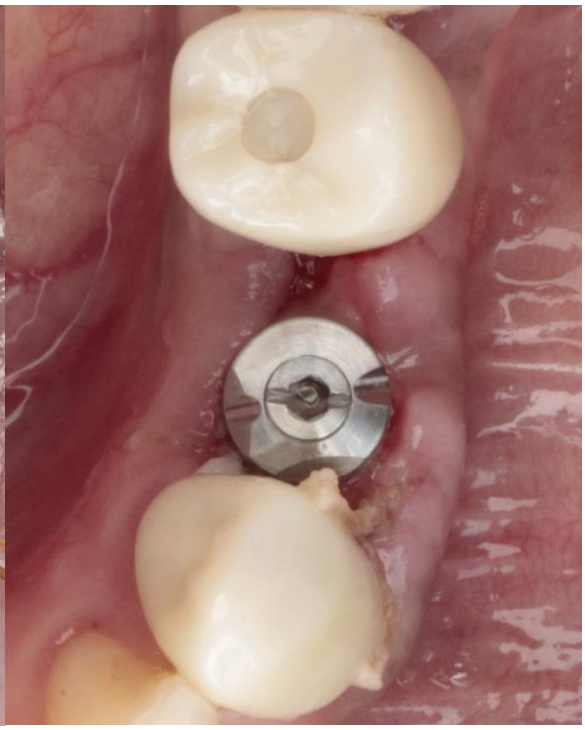
Surgical guide placed.



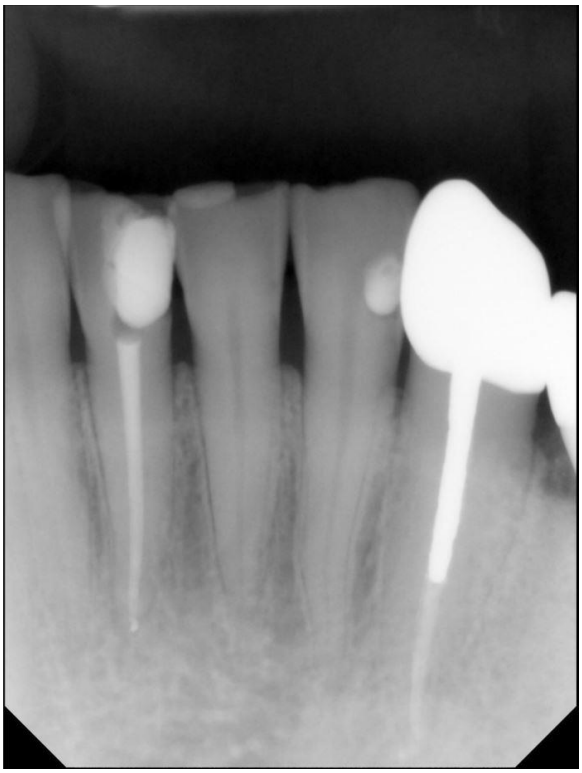
Implant placed.



Wound closure.



One week after implant placement.

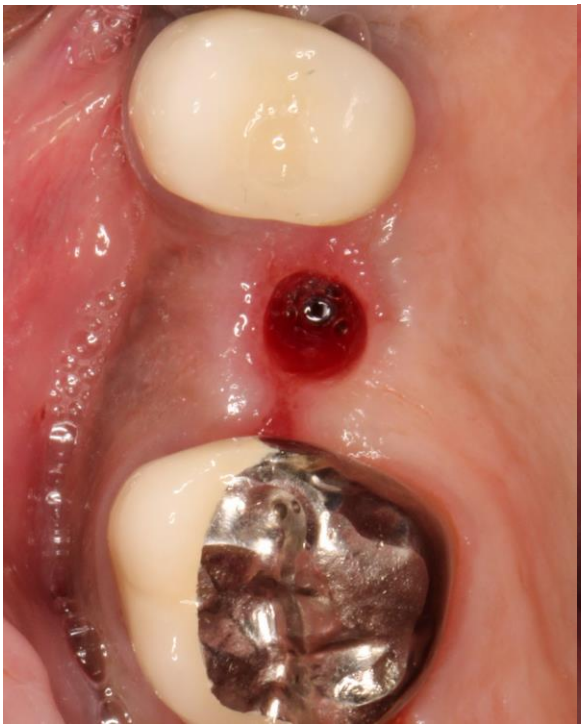


Radiograph to assess proximity to tooth #22.

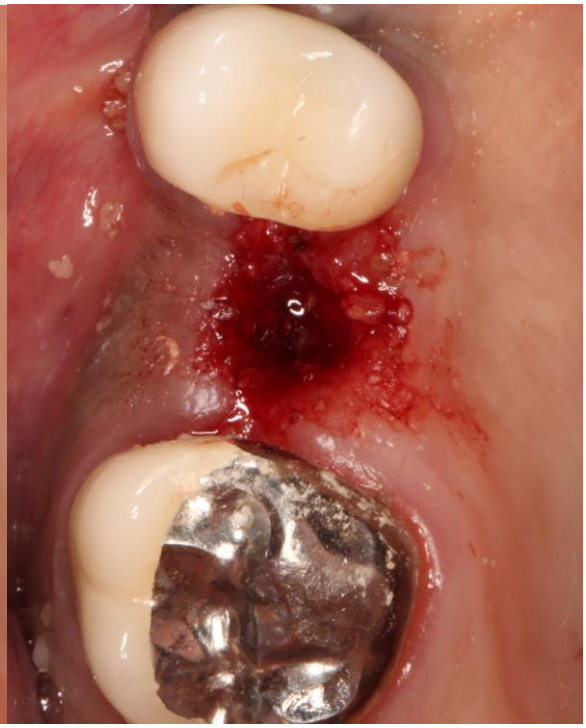
Case 18. Surgeon: MAJ Daniel Brockway **Date:** 4/4/2019
Diagnosis: Failed implant #3

Failed implant.

Explanted fixture.

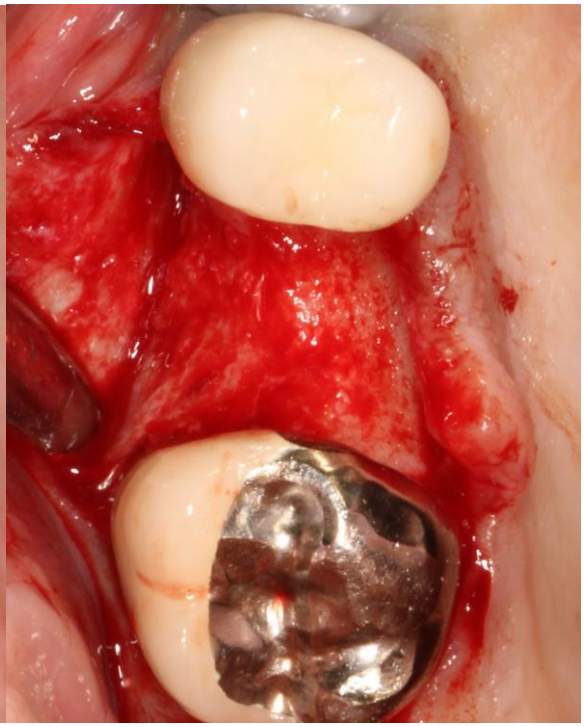


Residual alveolar defect.

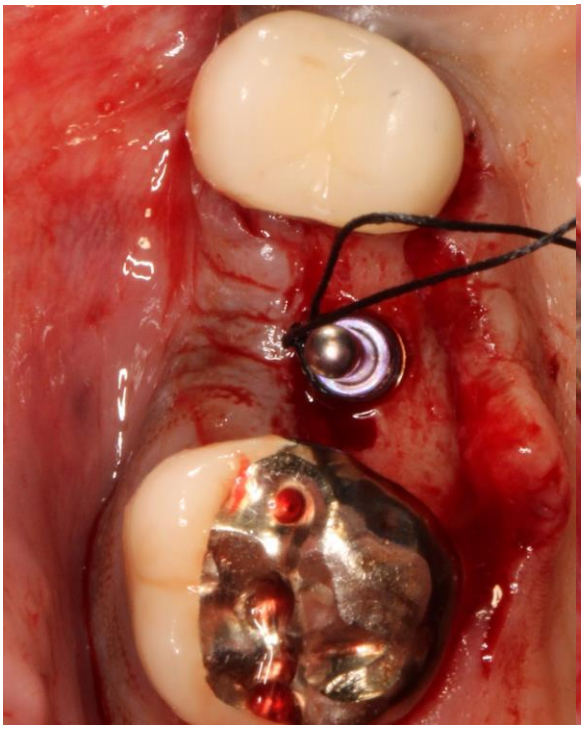


Laser generated blood clot.

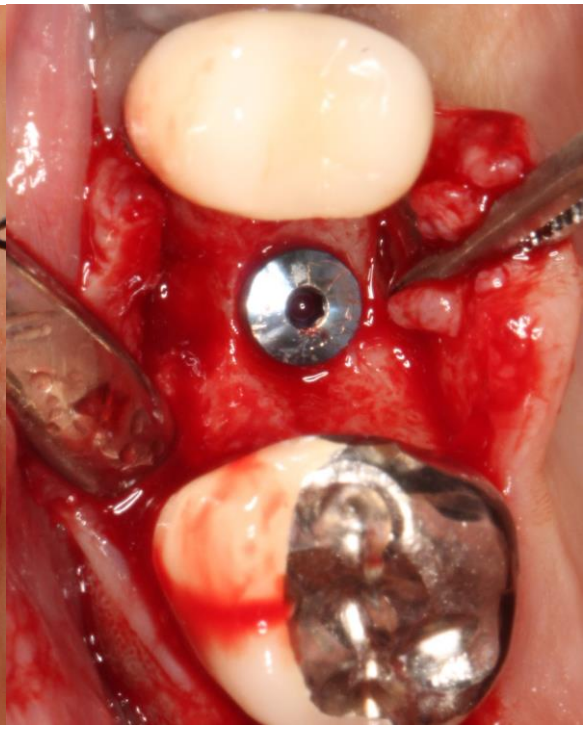
Two weeks after RPG.



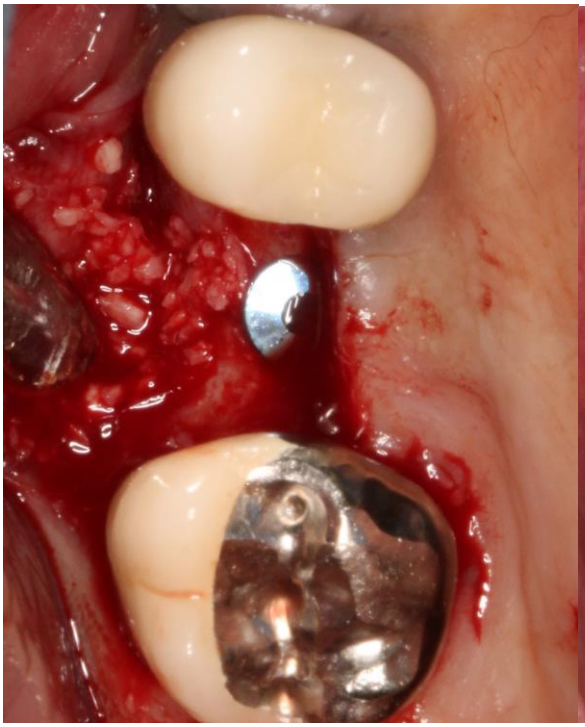
Flap reflected during implant surgery.



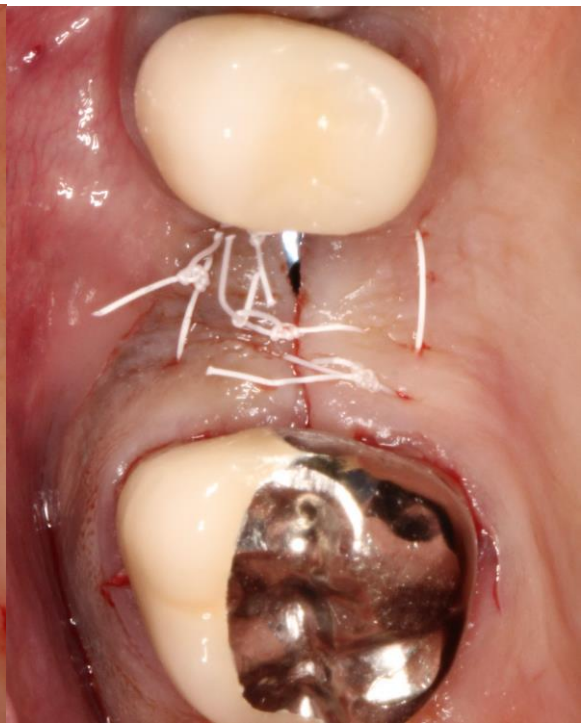
Direction indicator placed.



Implant placed.



Overlay graft applied.



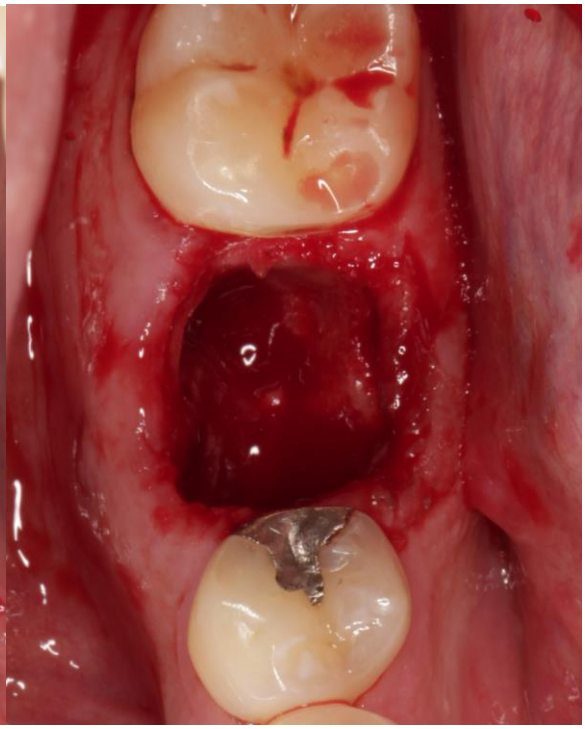
Wound closure.

Radiograph after implant placement.

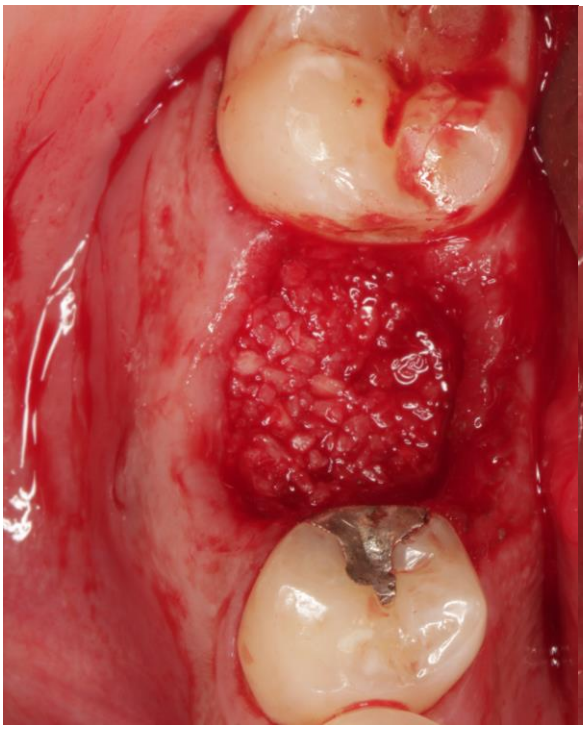
Two weeks after Implant placement

Case 19. Surgeon: CPT Rick Hill **Date:** 8/30/2017
Diagnosis: Nonrestorable tooth #30 (insufficient tooth structure)

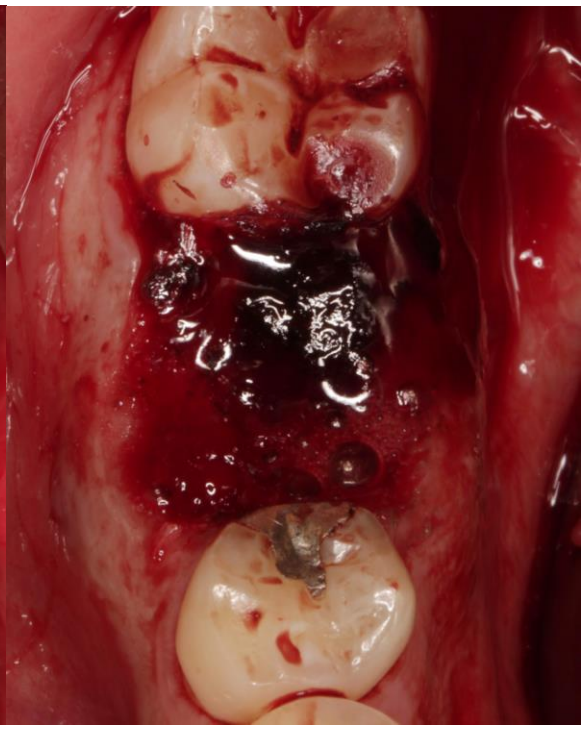
Baseline.



Elian class 2 extraction socket.



FDBA placed.

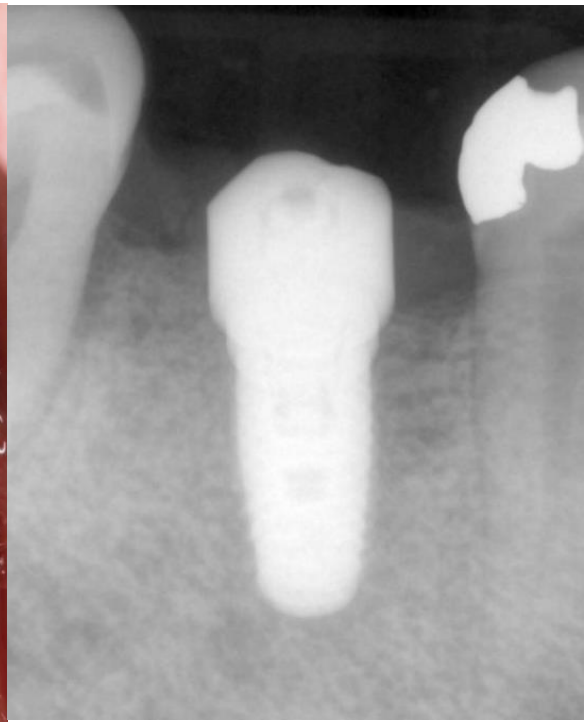


Laser generated blood clot.

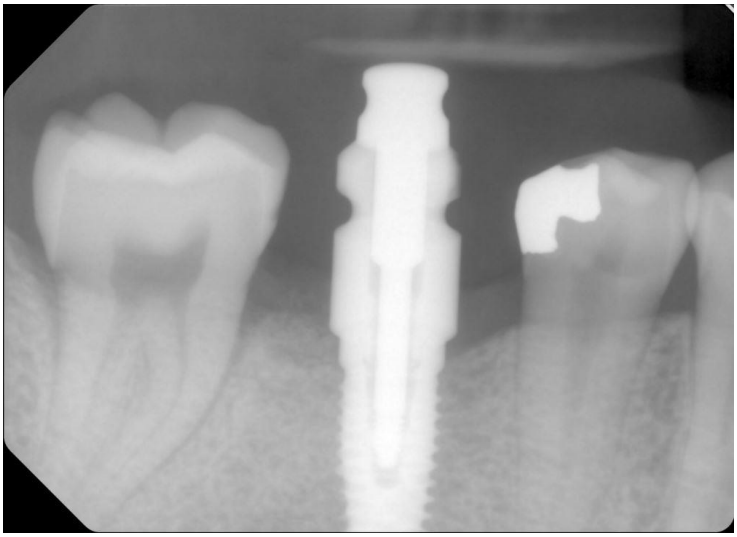
One week after RPG.

Four weeks after RPG.

Three months after RPG.



Implant was placed by MAJ Paul Seibel in Korea.

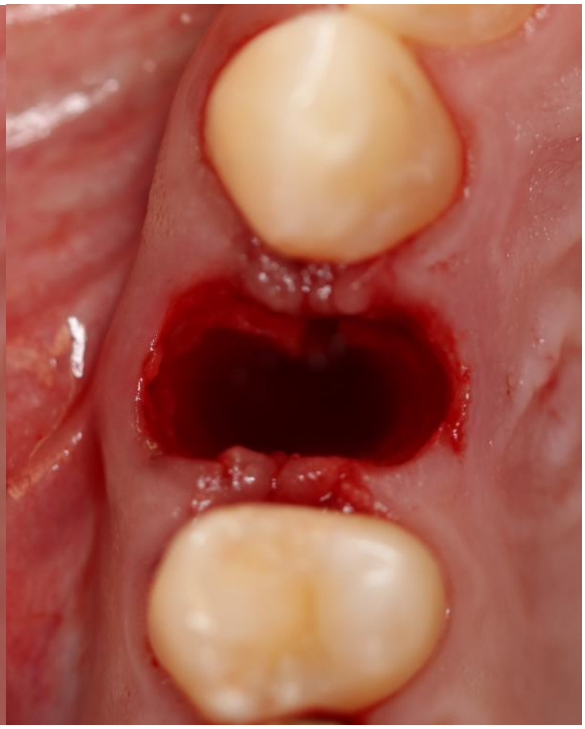


Radiograph of impression coping.

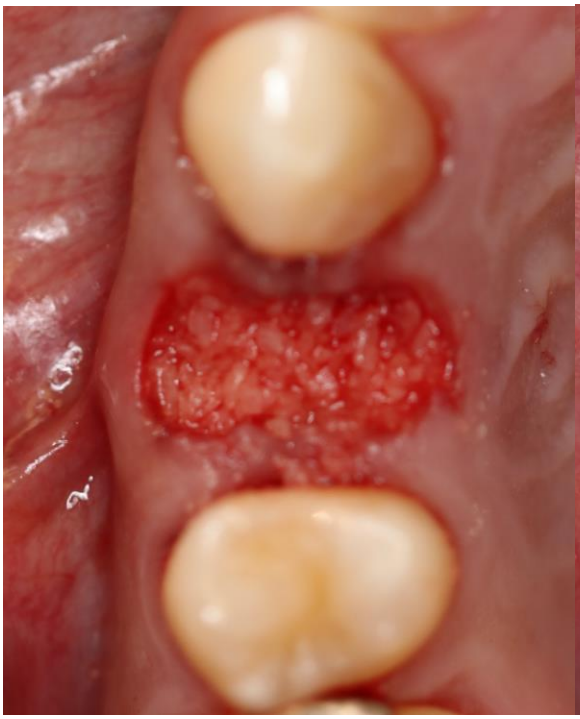
Dr. Barry Goldman is providing restorative treatment for this patient in Korea.

Case 20. Surgeon: CPT Sarah Vargas **Date:** 1/22/2020
Diagnosis: Nonrestorable #5 (fracture, insufficient tooth structure)

Baseline.



Minimally traumatic extraction.



FDBA placed.

Laser generated blood clot.

One week after RPG.

Five weeks after RPG.

Appendix 2: Nd:YAG Laser Application at Immediate Implant Sites

All patients presented to the Department of Periodontics, Army Postgraduate Dental School, Uniformed Services University of the Health Sciences, Fort Gordon, Georgia. All were periodontally and systemically healthy except as indicated.

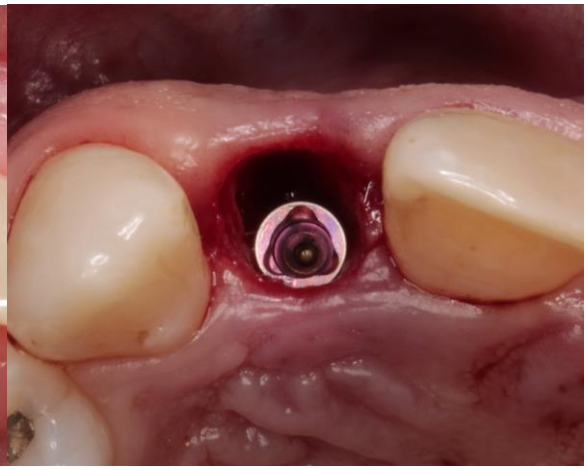
Abbreviation

FDBA: Freeze-dried bone allograft

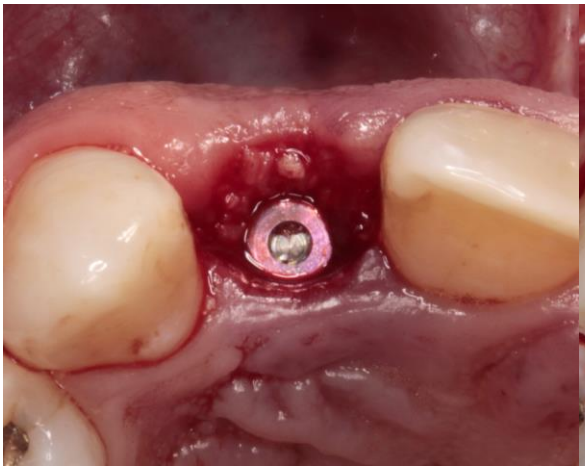
GBR: Guided bone regeneration

Case 1. Surgeon: MAJ Caitlin Reddy **Date of surgery:** 1/5/2017
Diagnosis: Nonrestorable tooth #7 (post failure, insufficient remaining tooth structure)

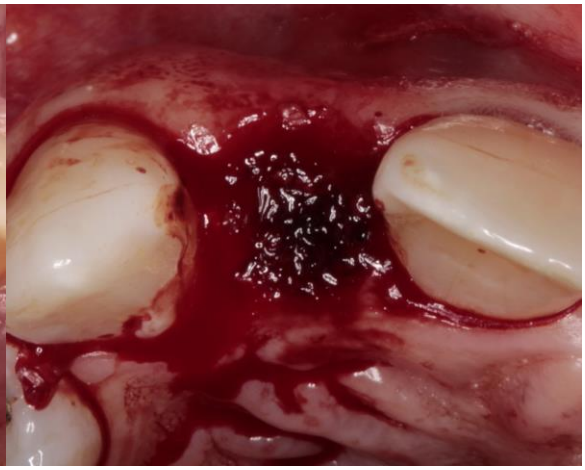
Baseline.



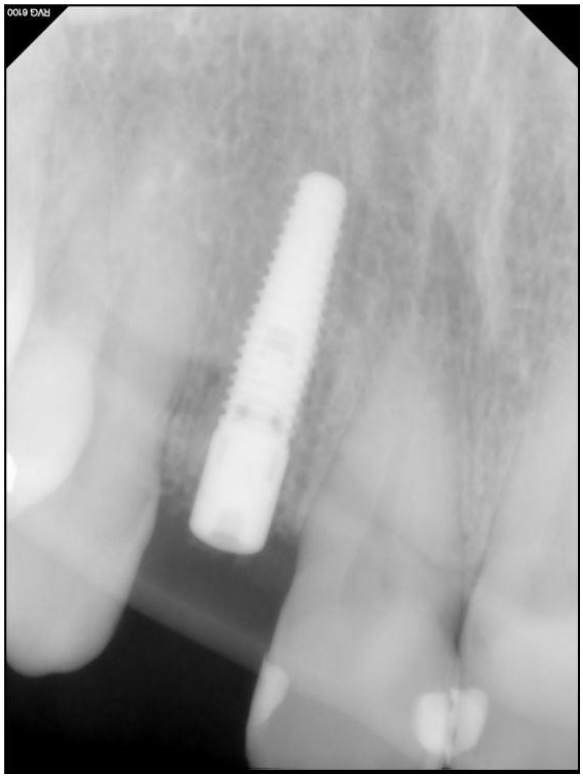
Immediate implant placed.



FDBA placed.



Laser generated clot covering implant.



Radiograph at immediate implant placement.

Two weeks after immediate implant.

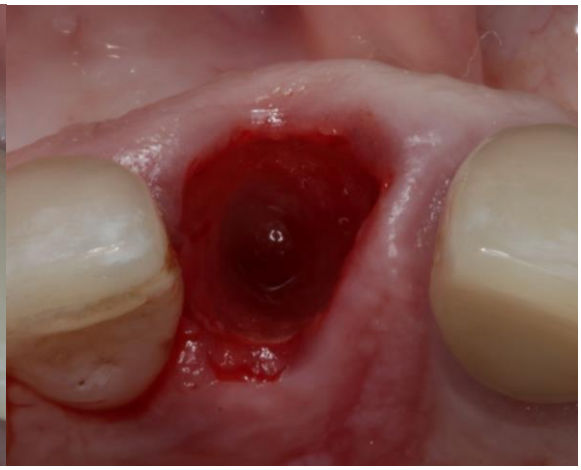
Final restoration by MAJ Nathan Kosiba.

Definitive restoration, implant #7.

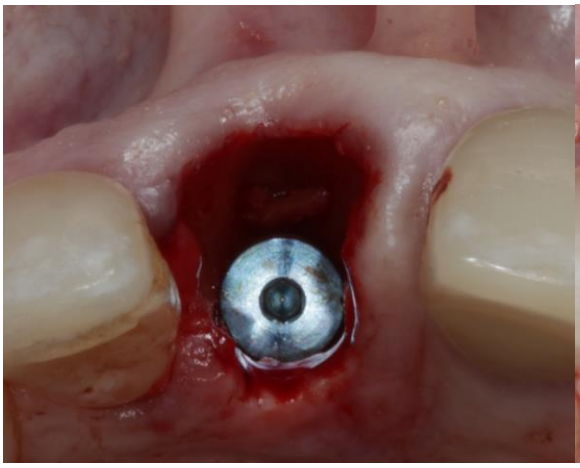
Stable radiographic bone levels following restoration.

Case 2. Surgeon: MAJ Justin Hoag **Date of surgery:** 1/3/2018
Diagnosis: Nonrestorable tooth #8 (fracture)

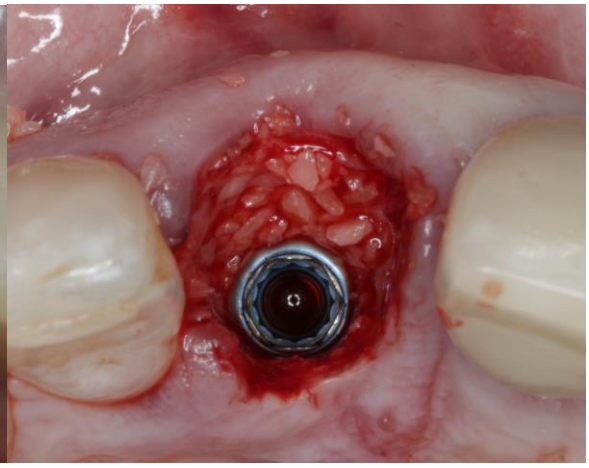
Baseline.



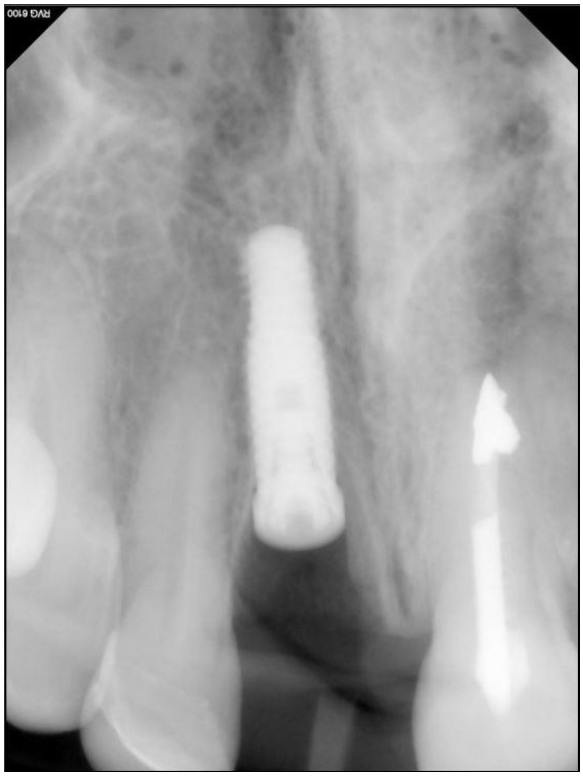
Minimally traumatic extraction.



Immediate implant placed.



FDBA placed in the peri-implant gap defect.



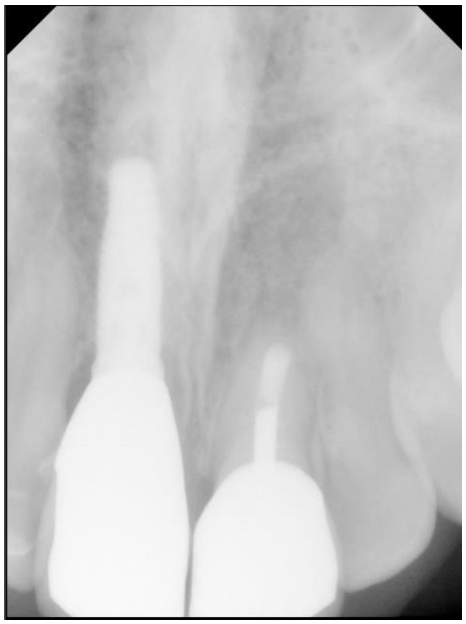
Radiograph at immediate implant placement.

Laser generated clot with provisional restoration, #8 position.

Two weeks after implant placement.

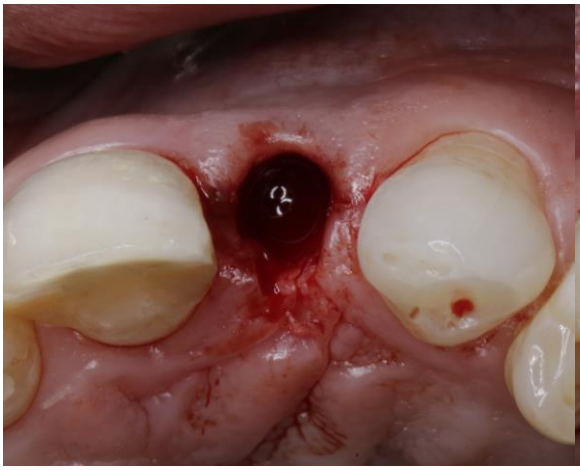
Seven months after implant placement.

Final restoration placed by CPT Ryan Coello.

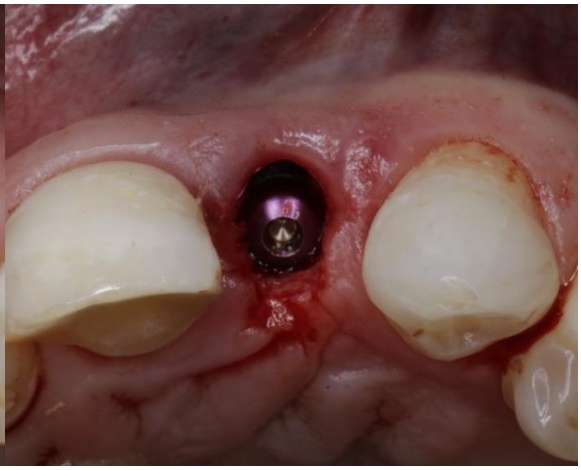


Radiograph at restoration delivery.

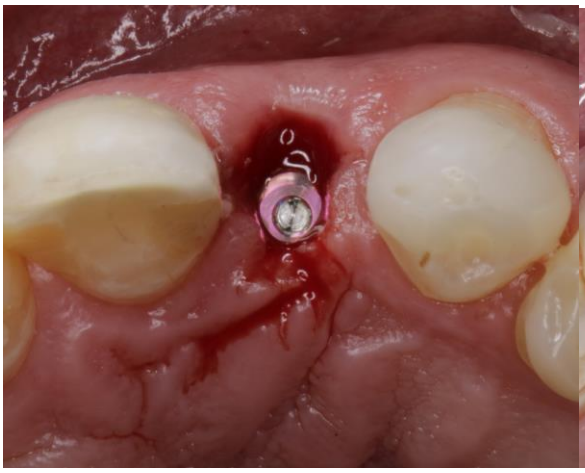
Case 3. Surgeon: MAJ Paul Seibel **Date of surgery:** 4/19/2018
Diagnosis: Microdont tooth #10 (poor esthetics and crown to root ratio)



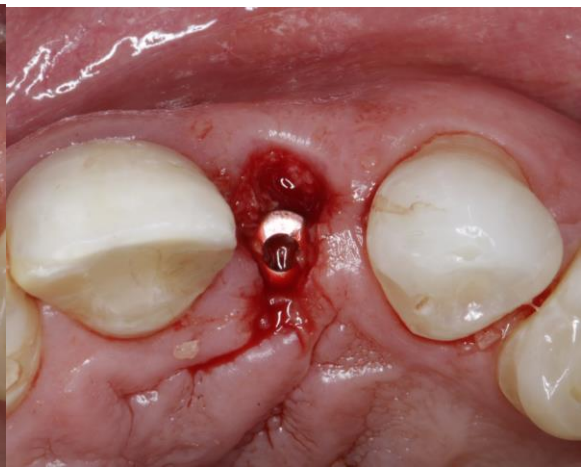
Minimally traumatic extraction.



Immediate implant placed.

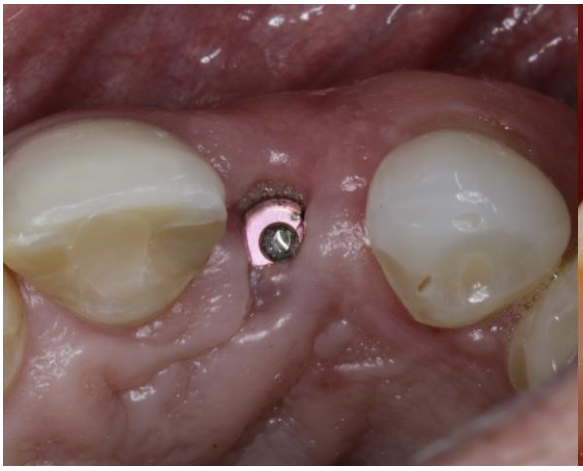


FDBA in the peri-implant gap defect.

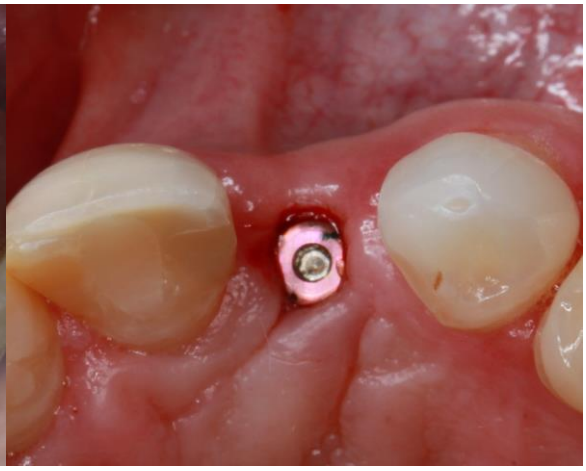


Laser generated blood clot.

Radiograph at immediate implant placement.



One week after implant placement.



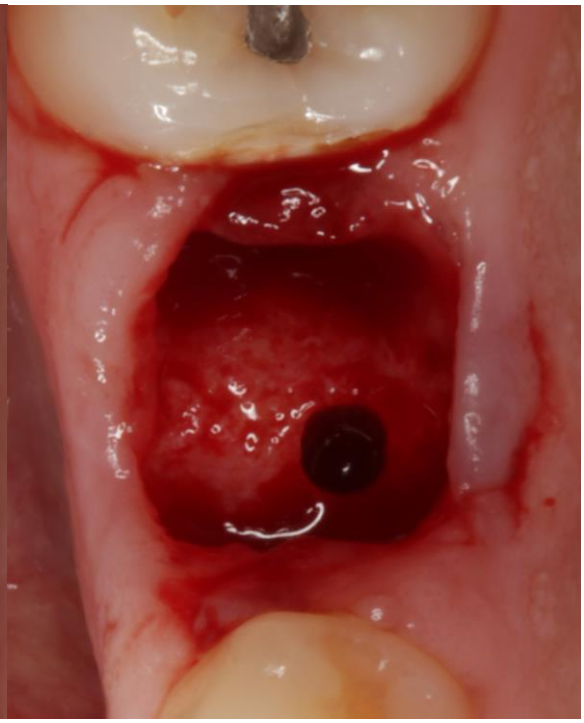
Two weeks after implant placement.

Provisional restoration placed by CPT Jin Xue two months after implant surgery.

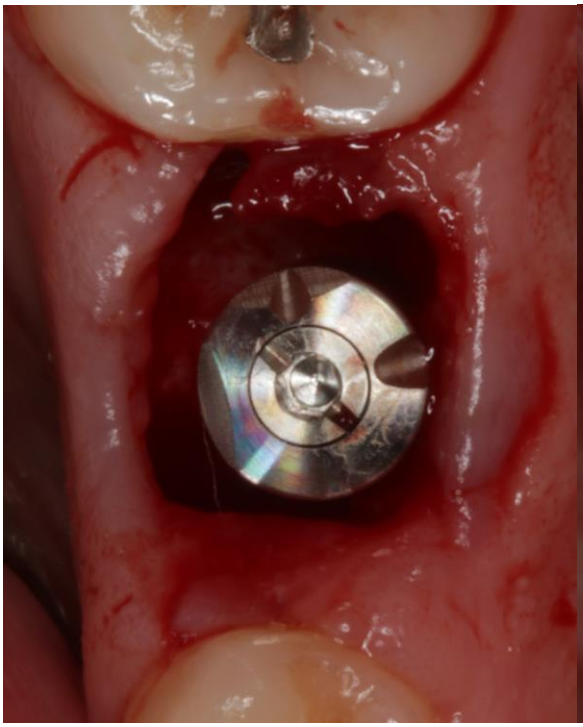
Radiograph at provisional restoration delivery.

Case 4. Surgeon: CPT Justin Hoag **Date of surgery:** 1/24/2018
Diagnosis: Over retained deciduous tooth #T with root resorption.

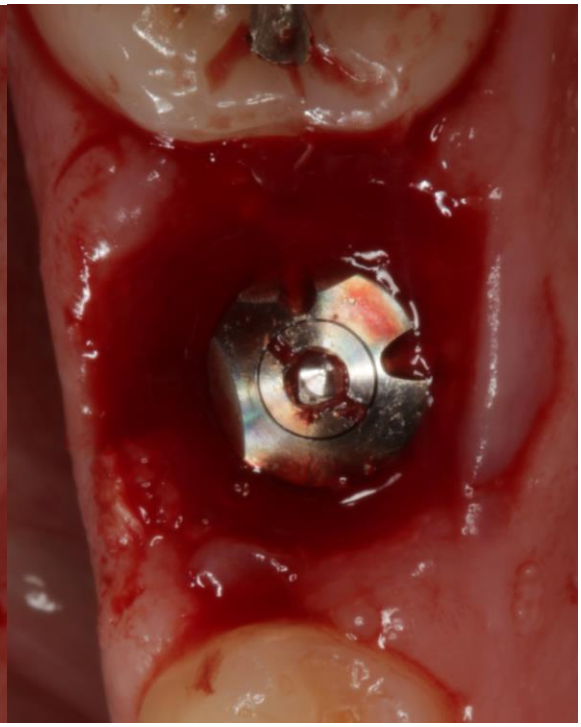
Baseline.



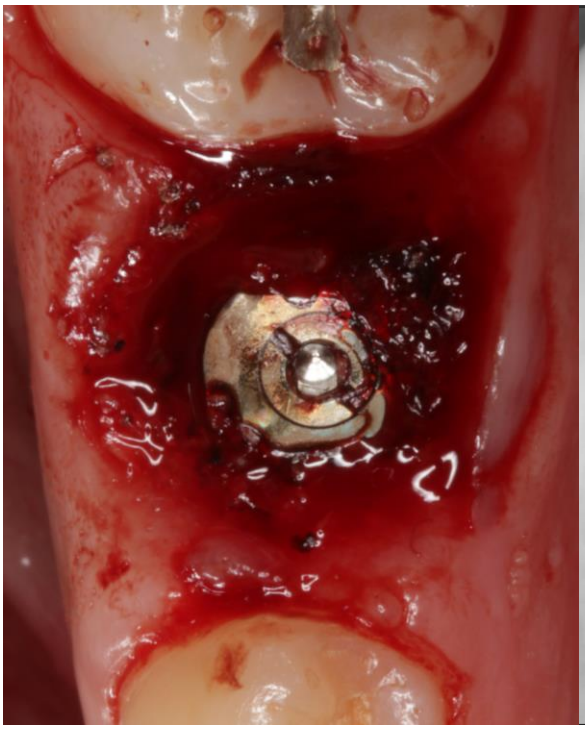
Minimally traumatic extraction.



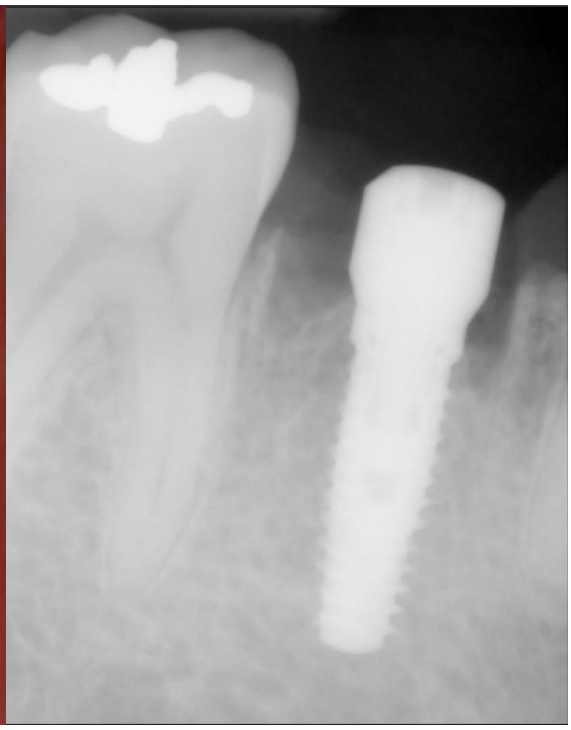
Immediate implant placed.



FDBA placed.



Laser generated blood clot.



Radiograph at implant placement.

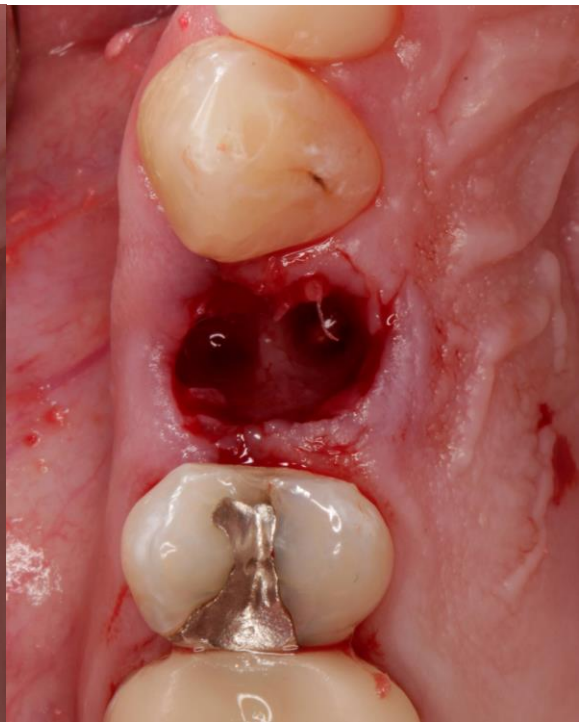
Two weeks after implant placement.

Final restoration delivered by CPT Jin Xue.

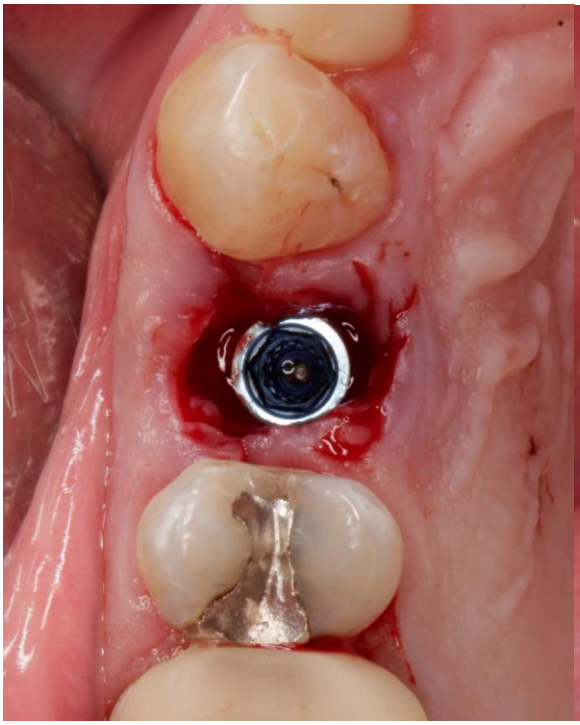
Radiograph at restoration delivery.

Case 5. Surgeon: CPT Rick Hill **Date of surgery:** 6/4/2018
Diagnosis: Nonrestorable tooth #5 (insufficient remaining tooth structure)

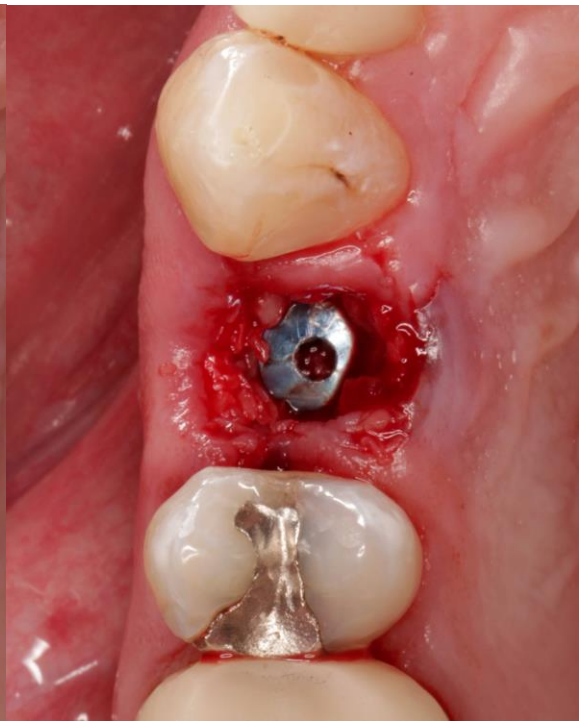
Baseline.



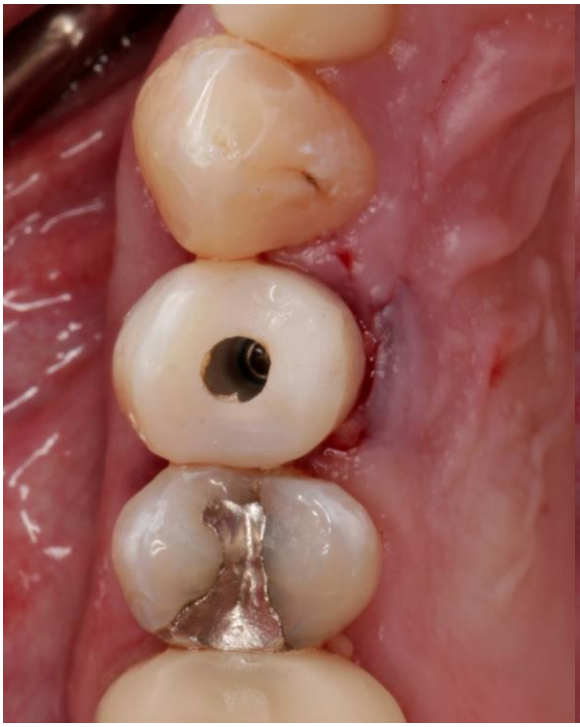
Minimally traumatic extraction.



Immediate implant placed.



FDBA placed, laser created clot not shown.



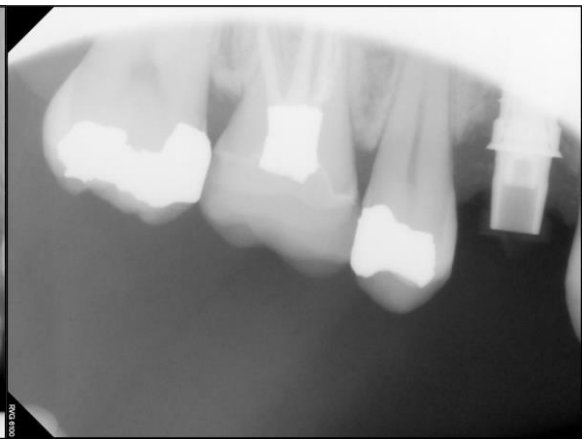
Immediate provisional restoration.

Two weeks after implant placement.

Immediate provisional restoration.

Two weeks after implant placement.

Radiograph at implant surgery.

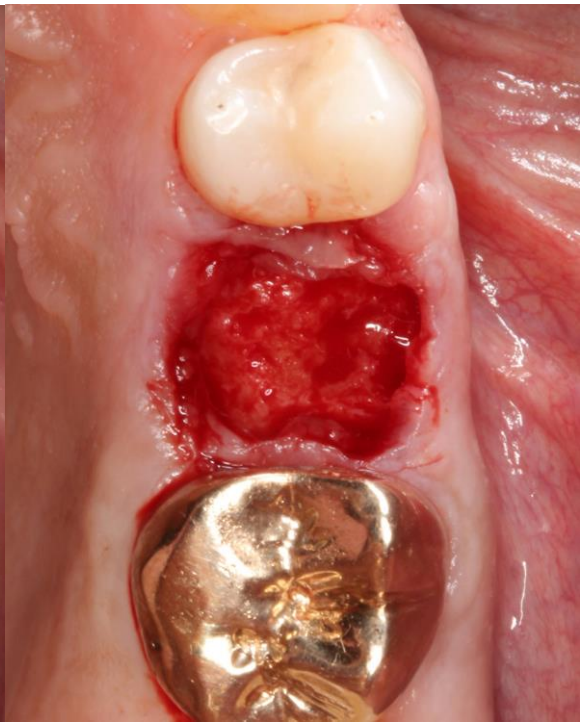


Radiograph of titanium base for definitive restoration.

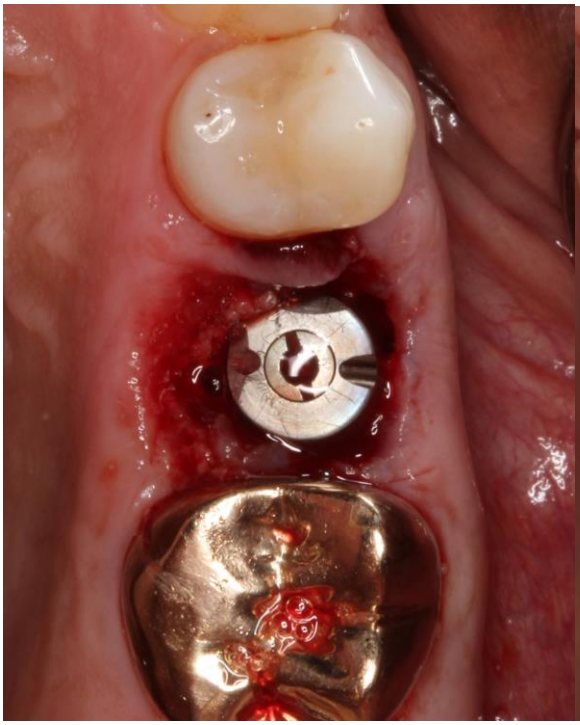
Restorative treatment completed by CPT Kellie O'Keefe, Department of Prosthodontics, Army Postgraduate Dental School.

Case 6. Surgeon: CPT Ryan McGary **Date of surgery:** 5/21/2018
Diagnosis: Over-retained primary tooth #J (root resorption, defective restoration)

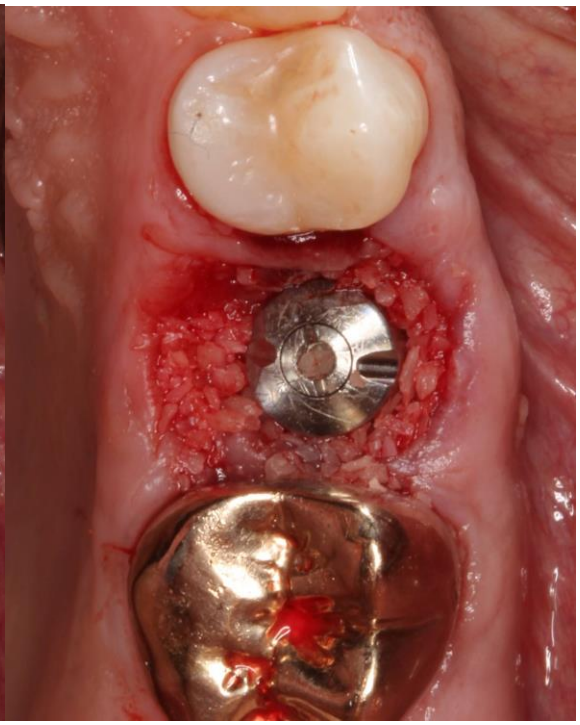
Baseline.



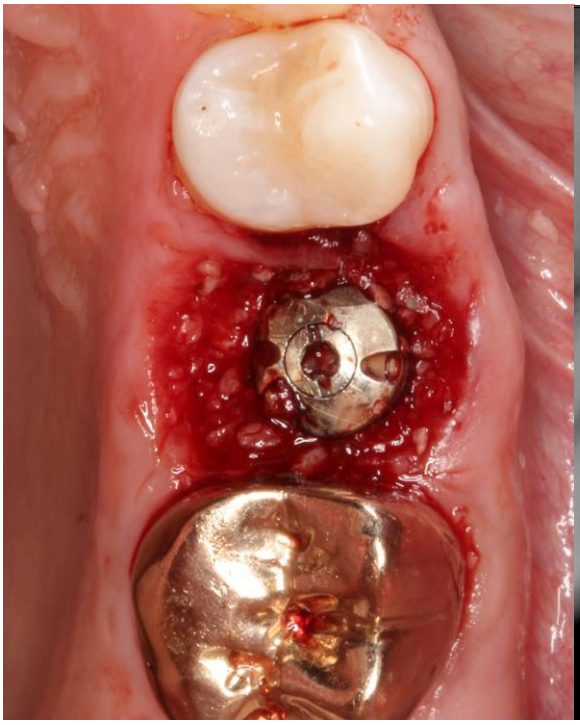
Minimally traumatic extraction.



Immediate implant placed.



FDBA placed.

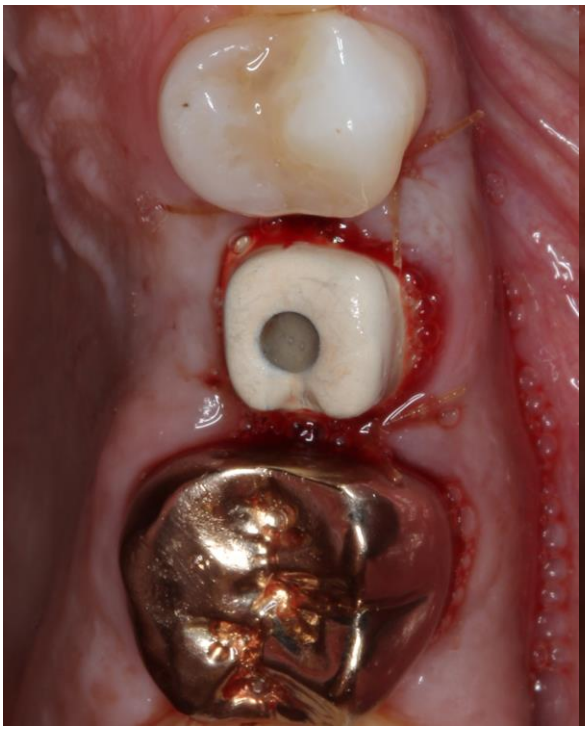


Laser generated blood clot.

Radiograph at implant placement.

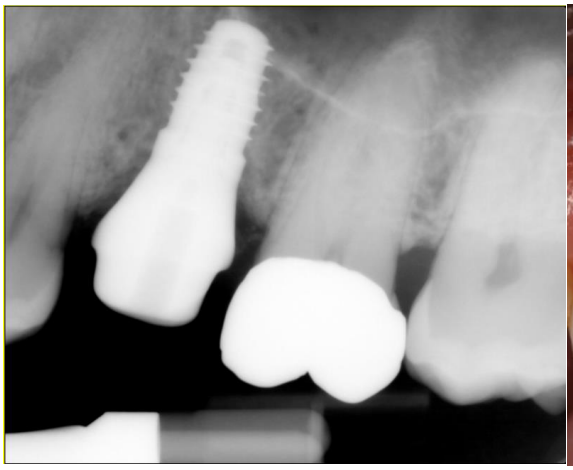
Four days after implant placement.

Ten days after implant placement.



Abutment four months after implant.

Definitive restoration.



Radiograph at abutment placement.

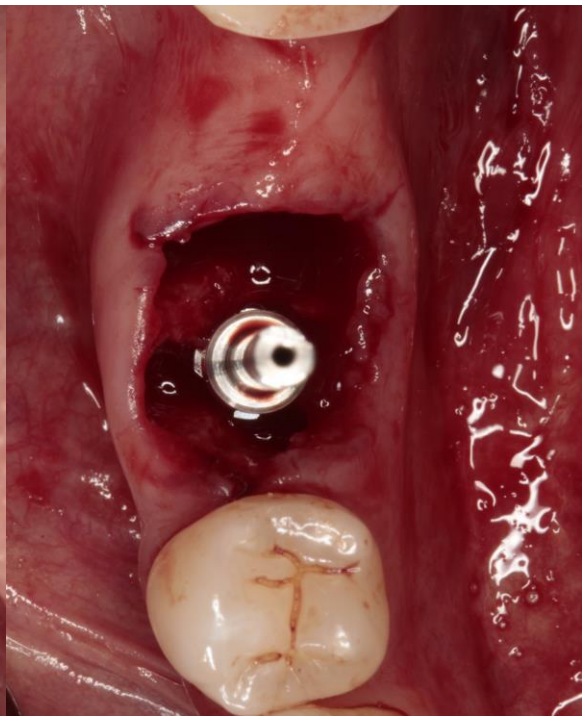
Final restoration, buccal view.

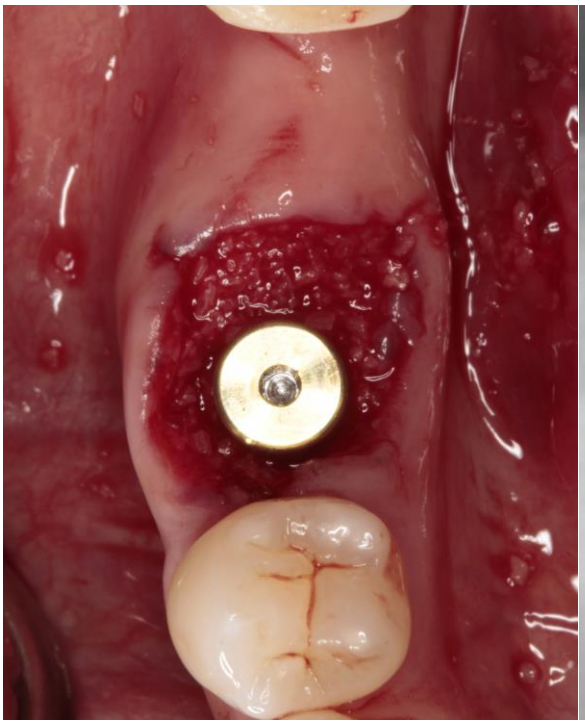
Case 7. Surgeon: CPT James Wilson **Date of surgery:** 2/7/2019
Diagnosis: Nonrestorable tooth #30 (insufficient remaining tooth structure)


Baseline.

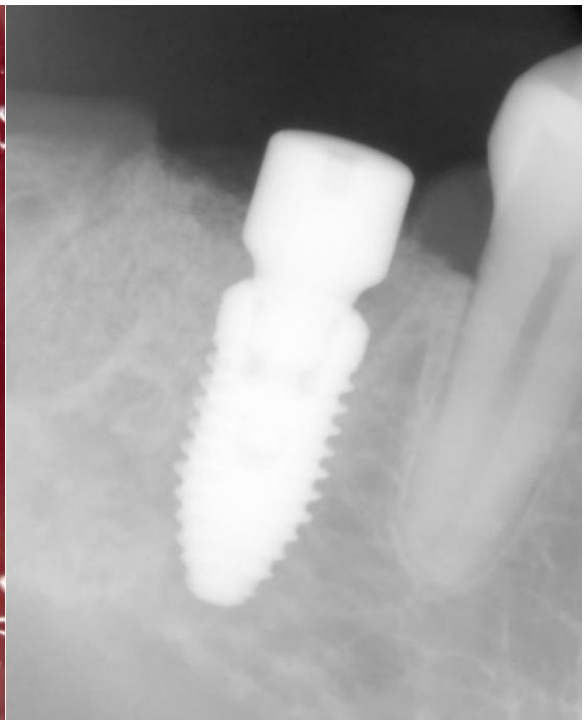

Sectioned tooth.


Minimally traumatic extraction.

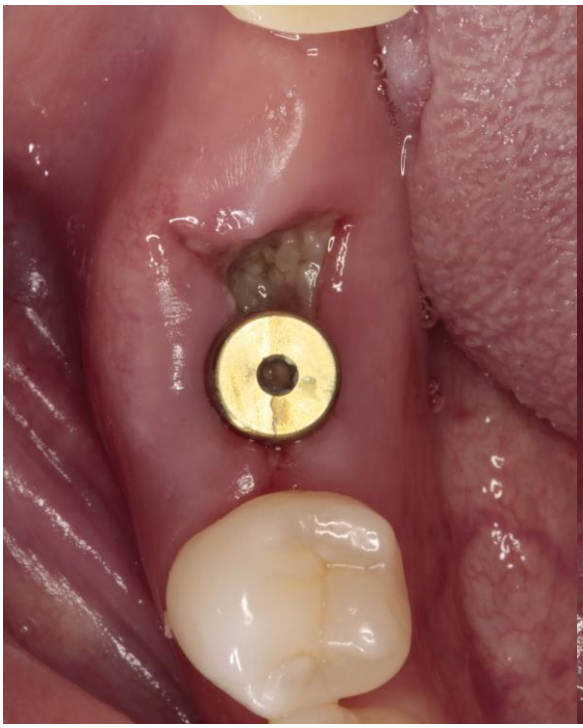

Implant drill demonstrating angulation.



FDBA placed, laser generated blood clot.



Radiograph at implant placement.



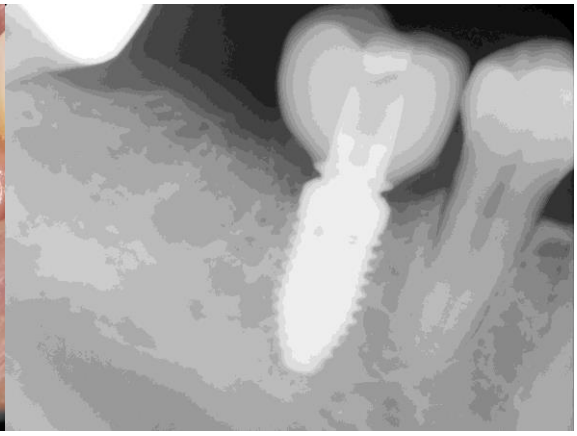
One week after implant placement

Two weeks after implant placement

Three weeks after implant placement.

Final restoration (CPT Kellie O'Keefe).

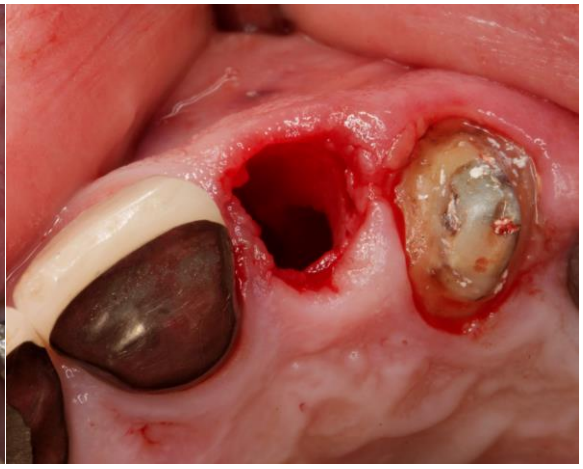
Final restoration, buccal view.

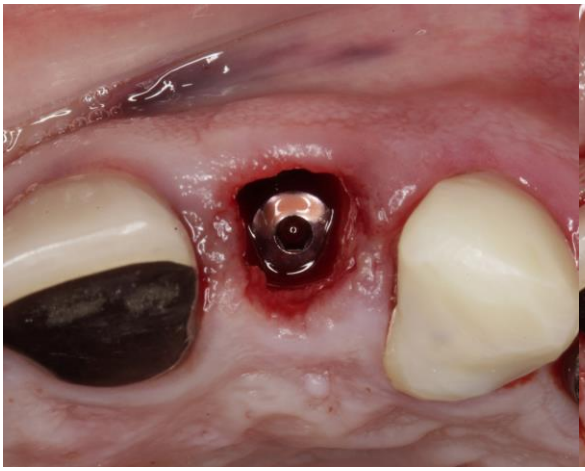


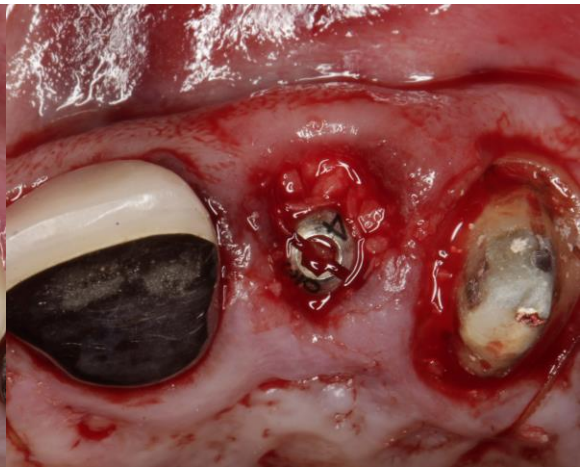
Final radiograph.

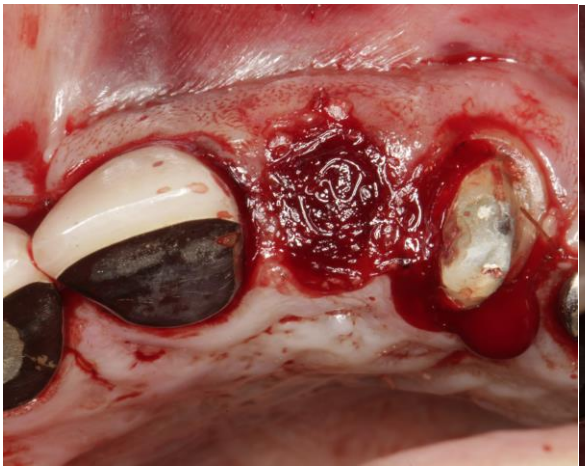
Case 8. Surgeon: CPT Dane Swenson **Date of surgery:** 2/13/2019
Diagnosis: Nonrestorable tooth #10 (insufficient tooth structure)


Baseline.

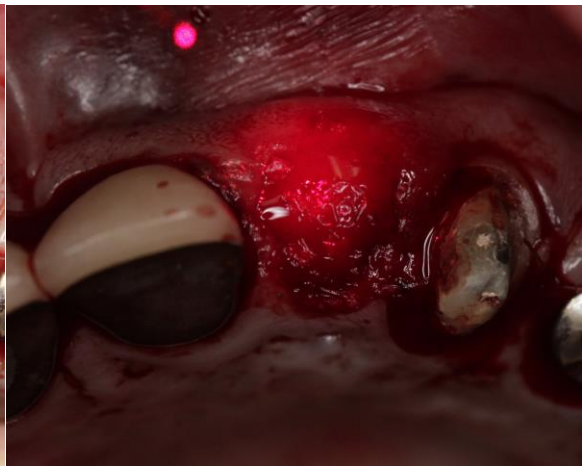

Minimally traumatic extraction.


Immediate implant and healing abutment.

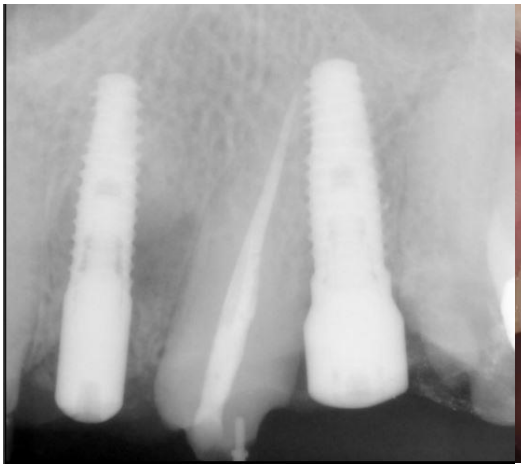

FDBA placed.



Laser generated blood clot.



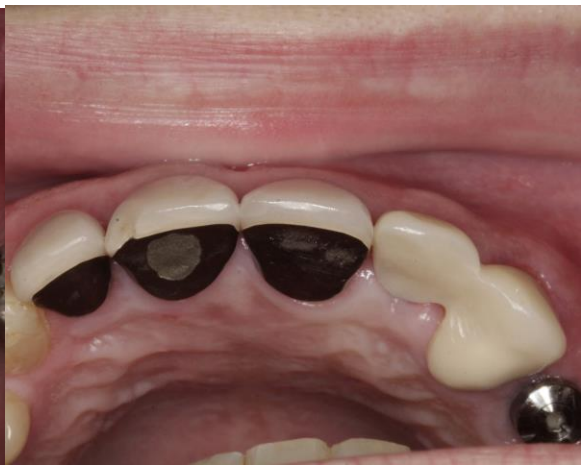
Photobiomodulation at the implant site.



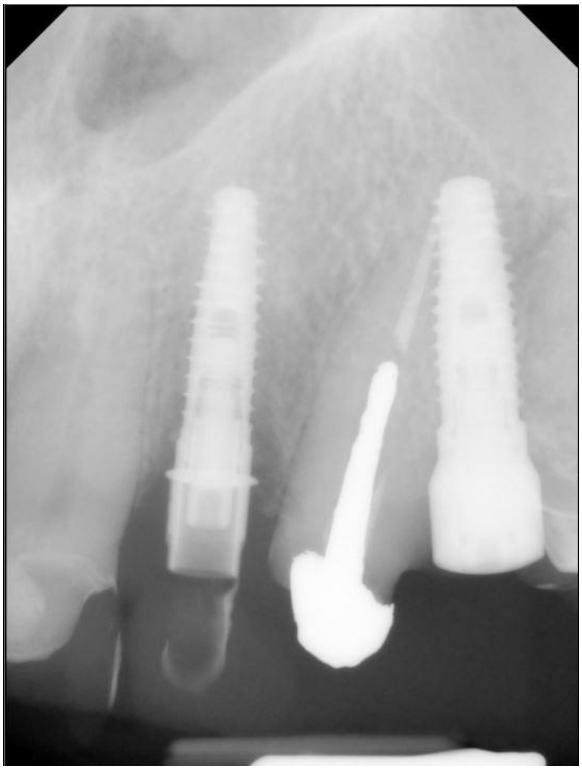
Radiograph at implant placement.

One week after implant placement, #10 position.

Two weeks after implant placement.



Cantilever provisional restoration, utilizing tooth #11 as the abutment.



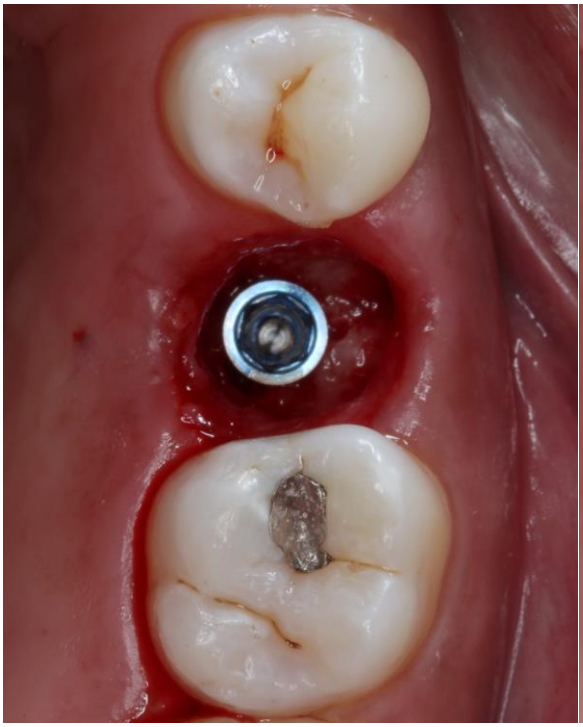
Radiograph demonstrating provisional restoration.

This patient is under the care of CPT Jenny Oh, Department of Prosthodontics, Army Postgraduate Dental School.

Case 9. Surgeon: CPT Ryan McGary **Date of surgery:** 2/6/2019
Diagnosis: Over-retained primary tooth #J with root resorption and ankylosis

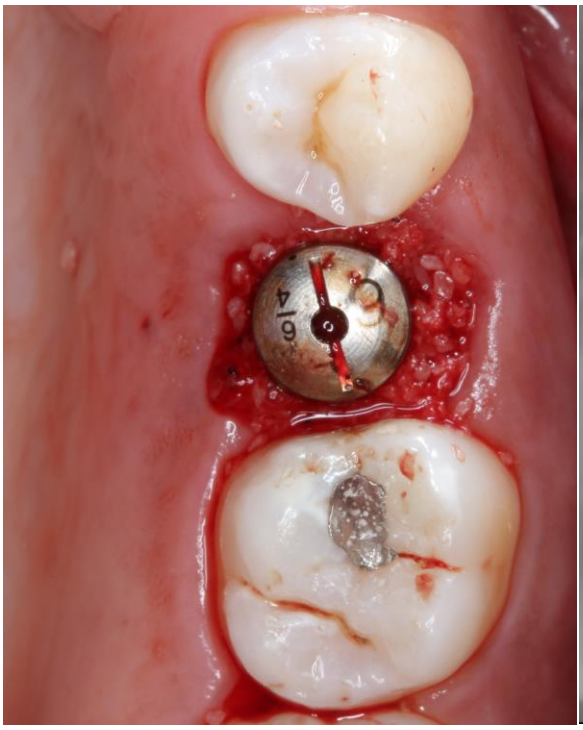
Baseline.

Minimally traumatic extraction.

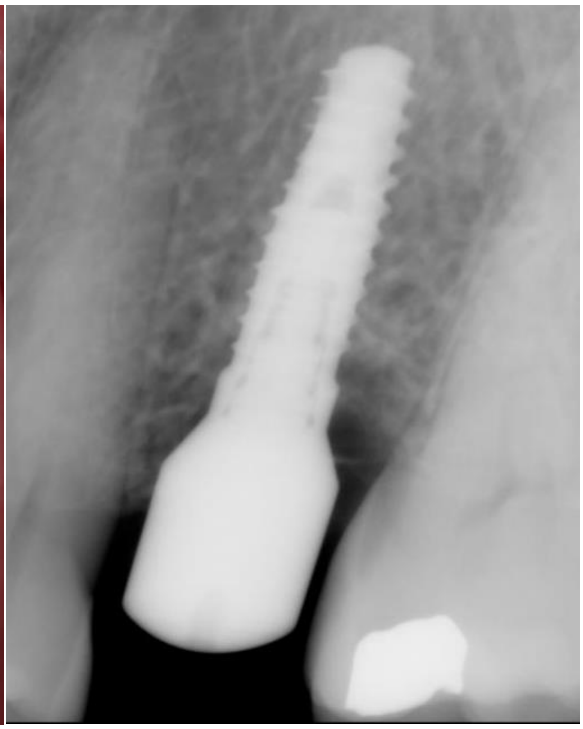


Implant placed.

Healing abutment placed.



FDBA placed, laser generated blood clot.



Radiograph at implant placement.

Two week after implant placement.

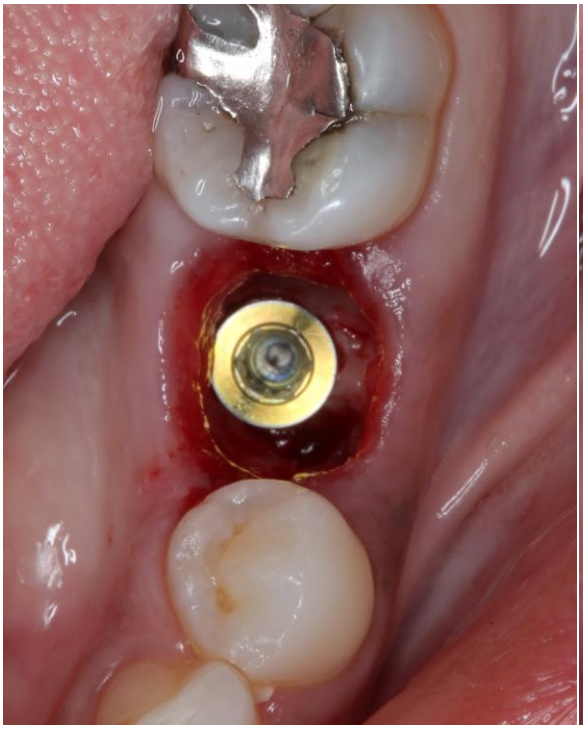
Seven weeks after implant placement.

Radiograph demonstrating final restoration delivered
by CPT Jake Wilding, Department of Prosthodontics.

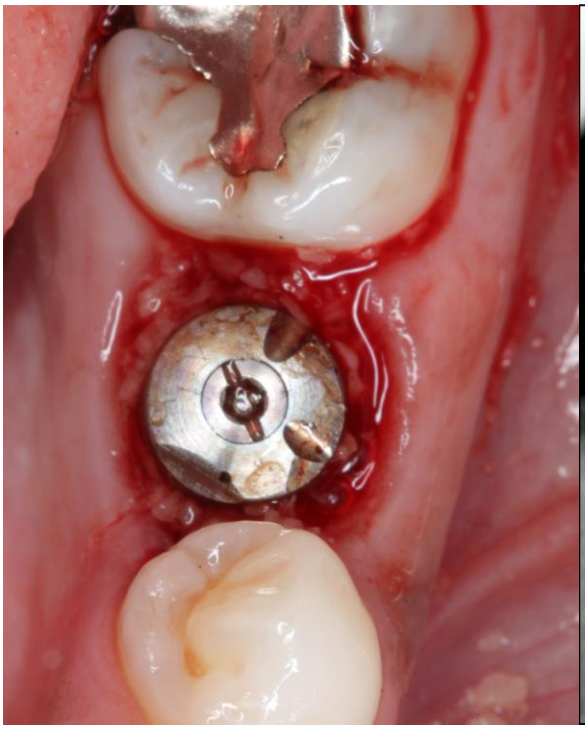
Case 10. Surgeon: CPT Ryan McGary **Date of surgery: 2/6/2019**
Diagnosis: Over-retained primary tooth #K (root resorption)


Baseline.

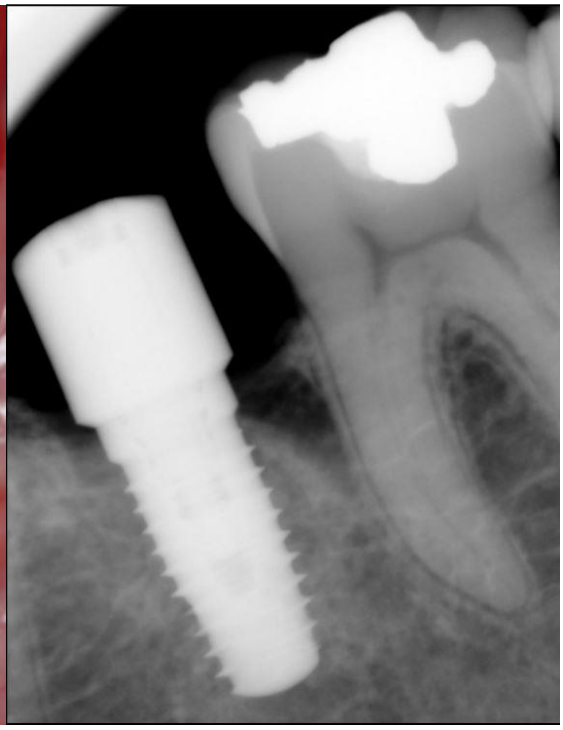

Minimally traumatic extraction.


Implant placed.


FDBA placed.

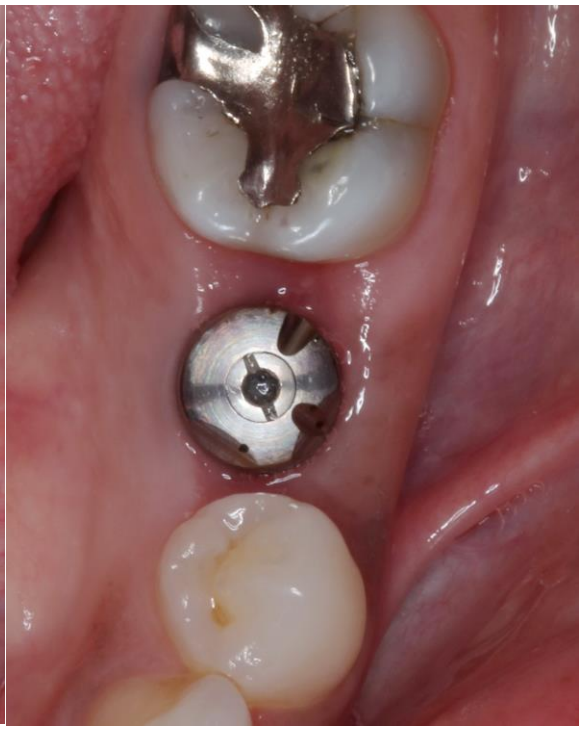


Laser generated blood clot.

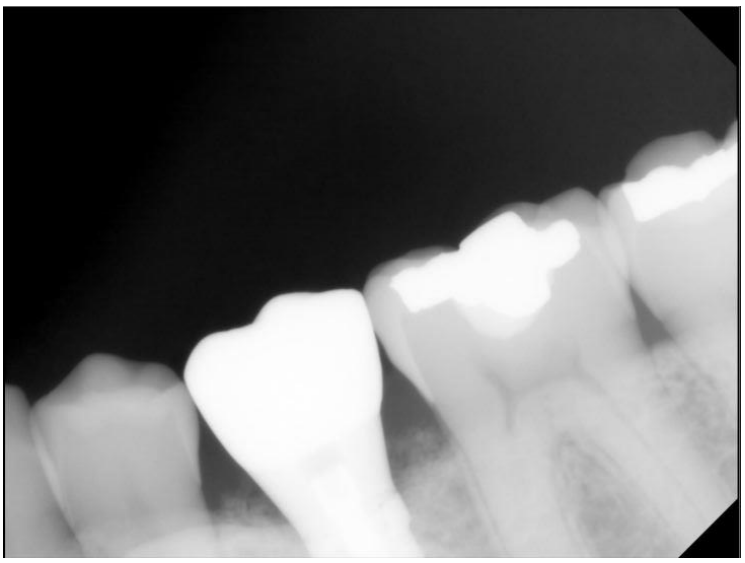


Radiograph at implant placement.

Two weeks after implant placement.



Seven weeks after implant placement.

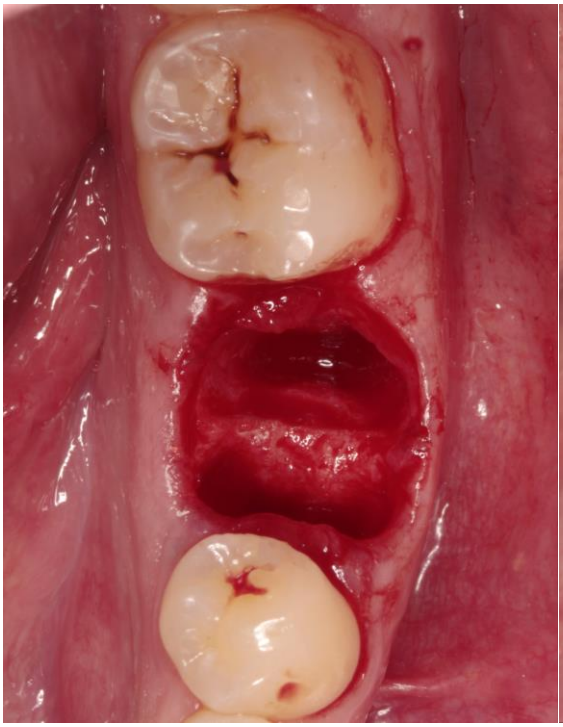


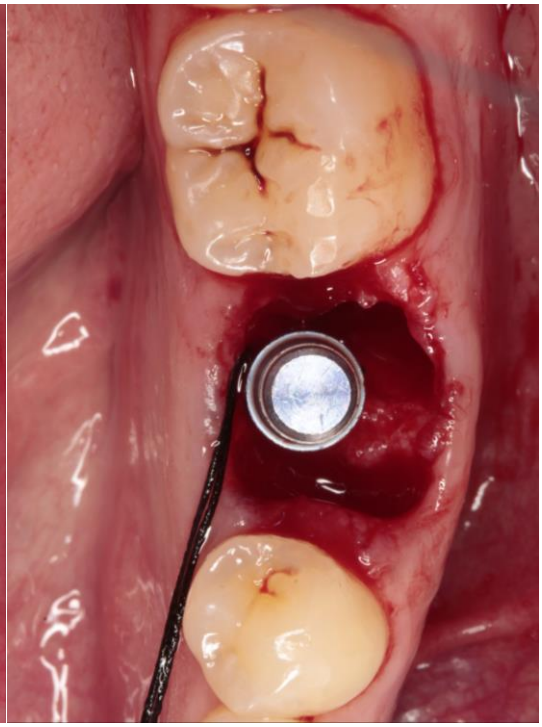
Radiograph demonstrating final restoration delivered by CPT Jake Wilding, Department of Prosthodontics, Army Postgraduate Dental School.

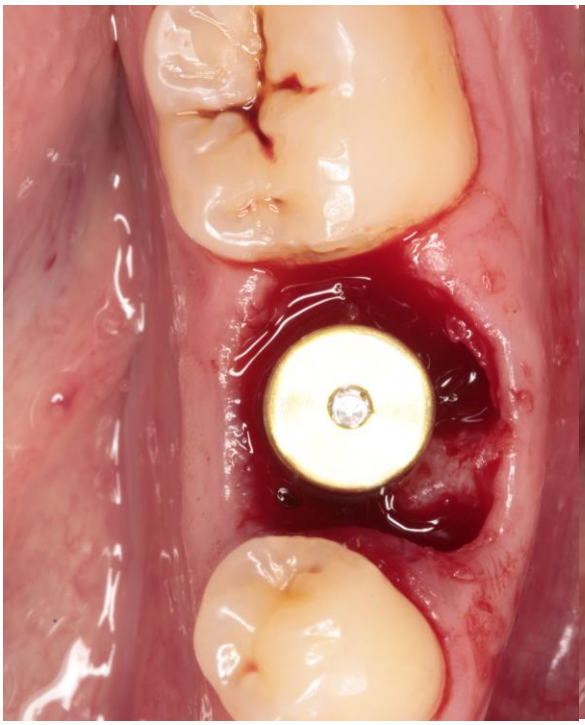
Case 11. Surgeon: CPT James Wilson **Date of surgery:** 3/11/2019
Diagnosis: Nonrestorable tooth #19 (vertical root fracture)


Baseline.

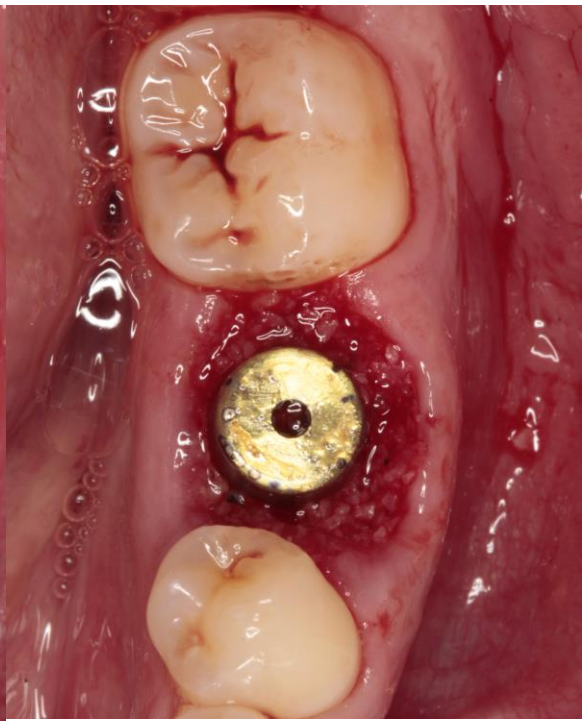

Tooth sectioned.


Minimally traumatic extraction.


Direction indicator.



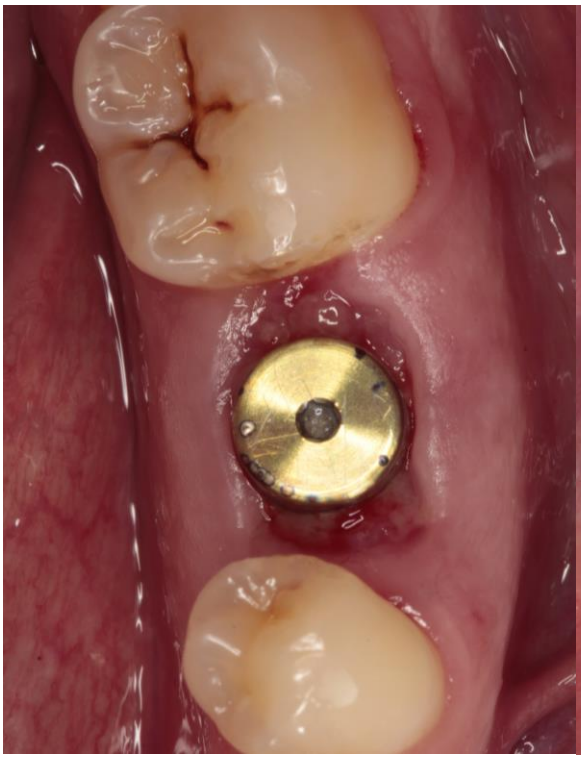
Implant and healing abutment placed.



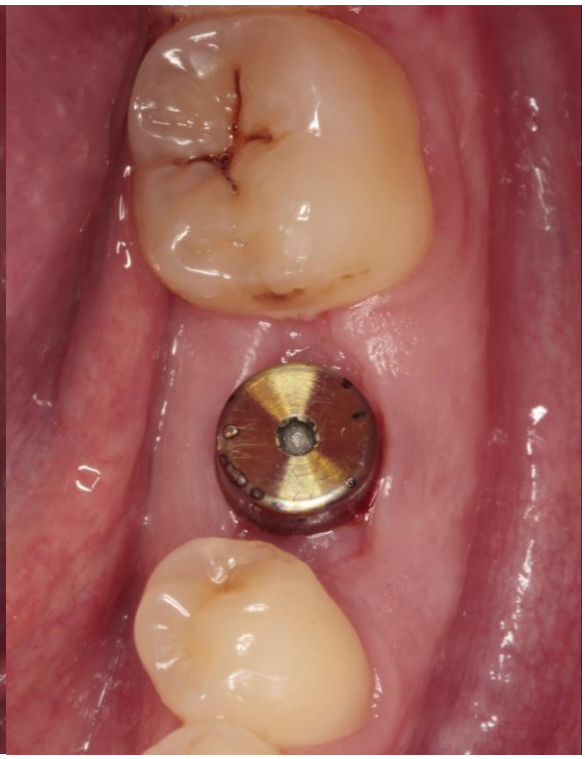
FDBA placed, laser generated blood clot.

Radiograph at implant placement.

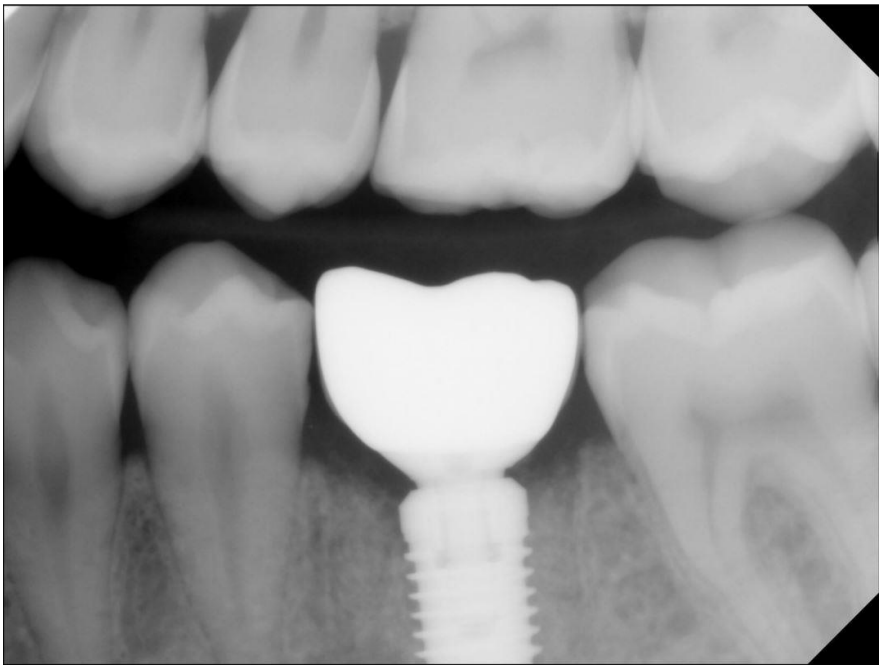
One week after implant placement.



Two weeks after implant placement.



Seven weeks after implant placement.

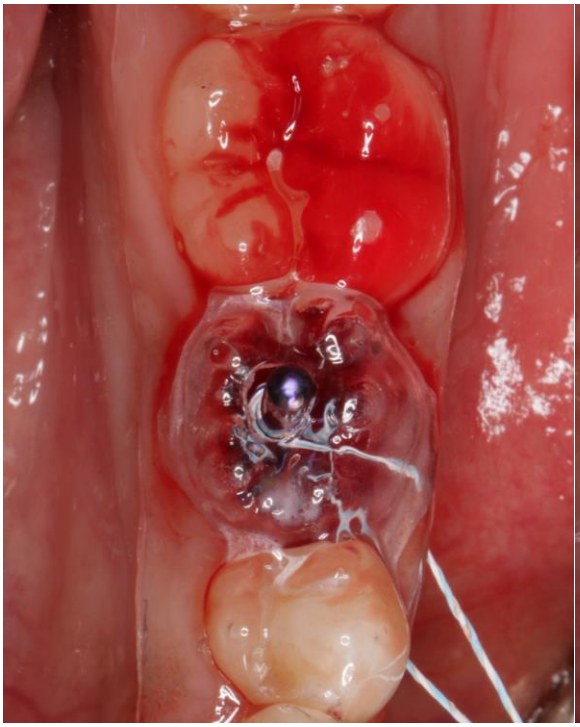


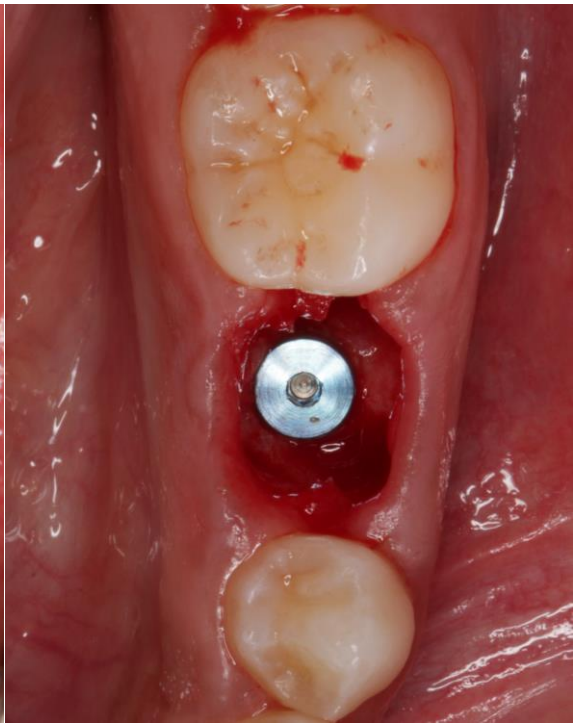
Radiograph demonstrating final restoration delivered by
LTC Sloan McLaughlin, Army Dental Laboratory.

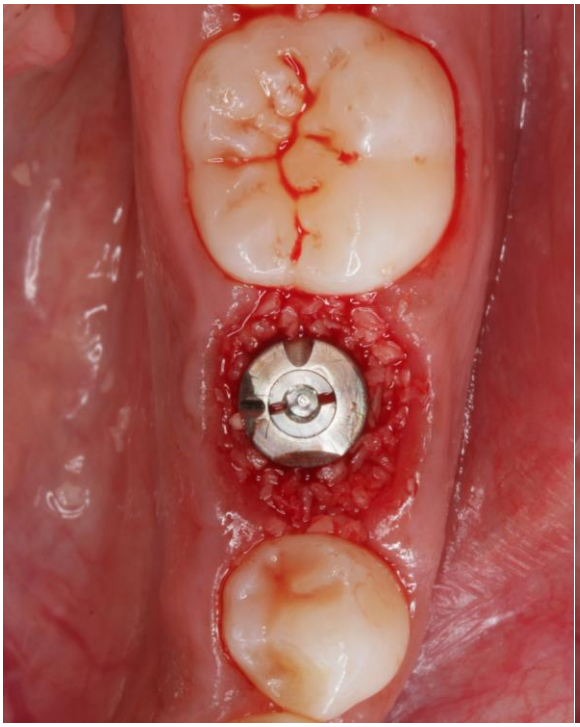
Case 12. Surgeon: MAJ Alicia Choi **Date of surgery:** 10/17/2019
Diagnosis: Over-retained primary tooth #K (root resorption and ankylosed root)


Baseline.

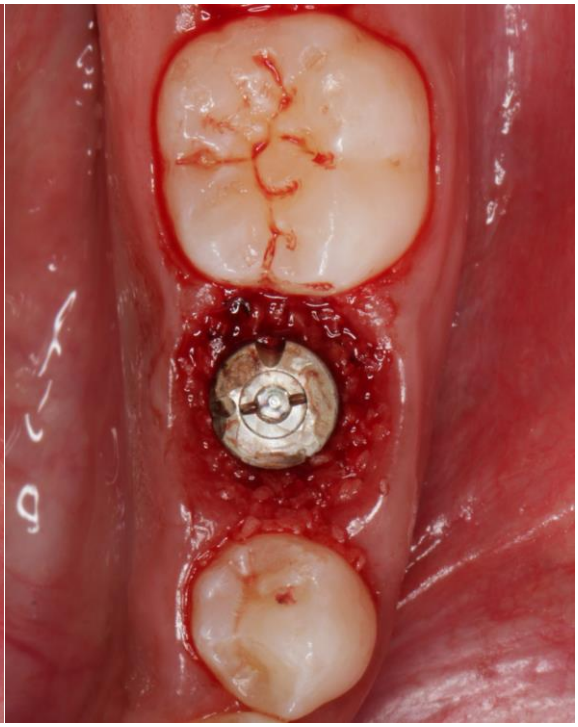

Minimally traumatic extraction.


Direction indicator.


Implant placed.



FDBA placed.

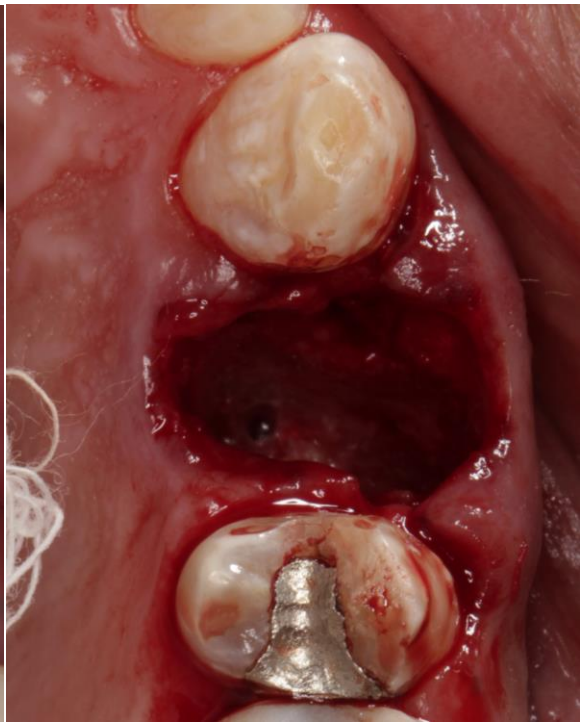


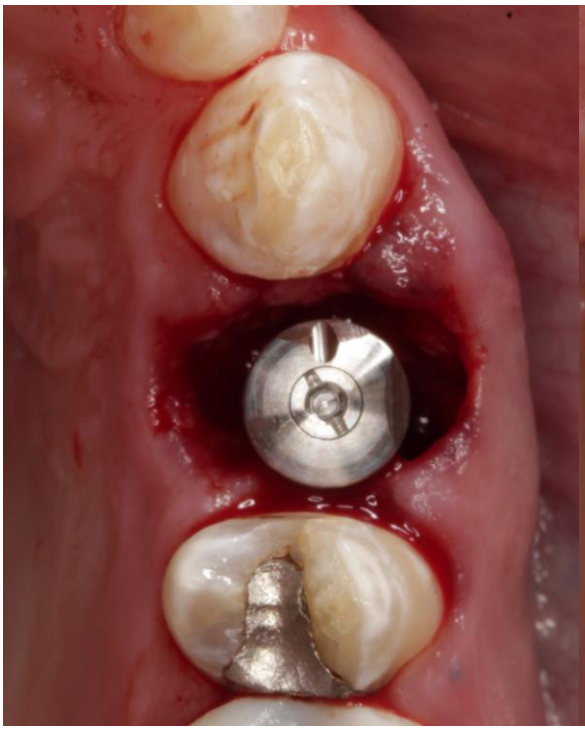
Laser generated blood clot.

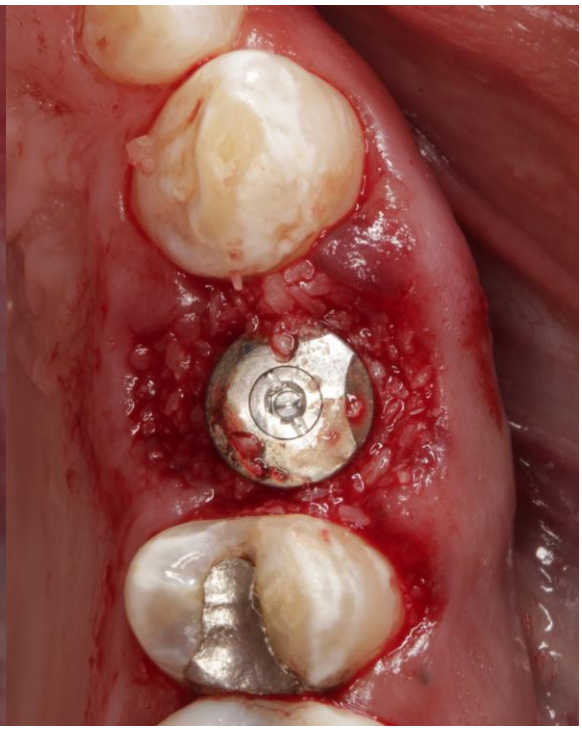
Radiograph at implant placement.

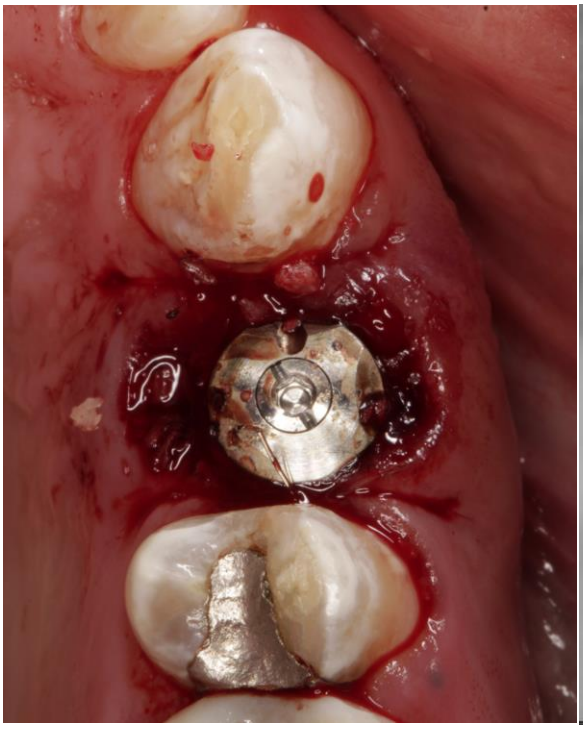
Case 13. Surgeon: CPT Rick Hill **Date of surgery:** 6/6/2018
Diagnosis: Nonrestorable tooth #12 (insufficient tooth structure)


Baseline.

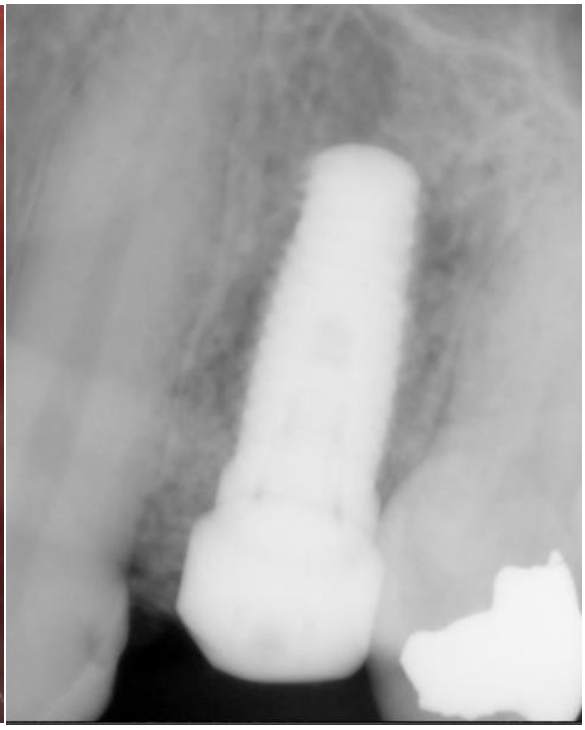

Minimally traumatic extraction.


Implant placed.


FDBA placed.



Laser generated blood clot.



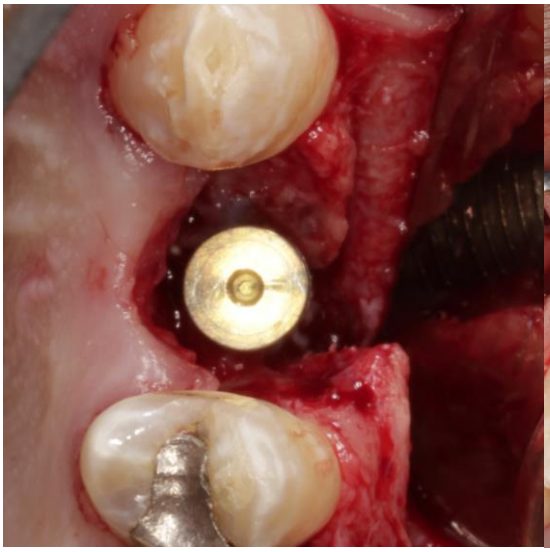
Radiograph at implant placement.

One day after implant placement.

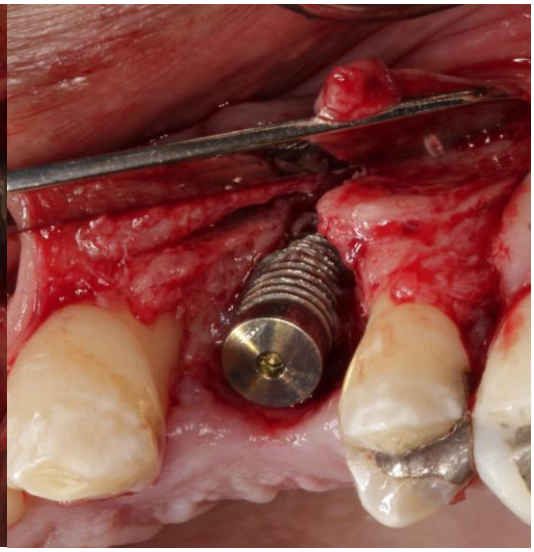
One week after implant placement.

Two weeks after implant placement.

Implant failure at postoperative week nine.

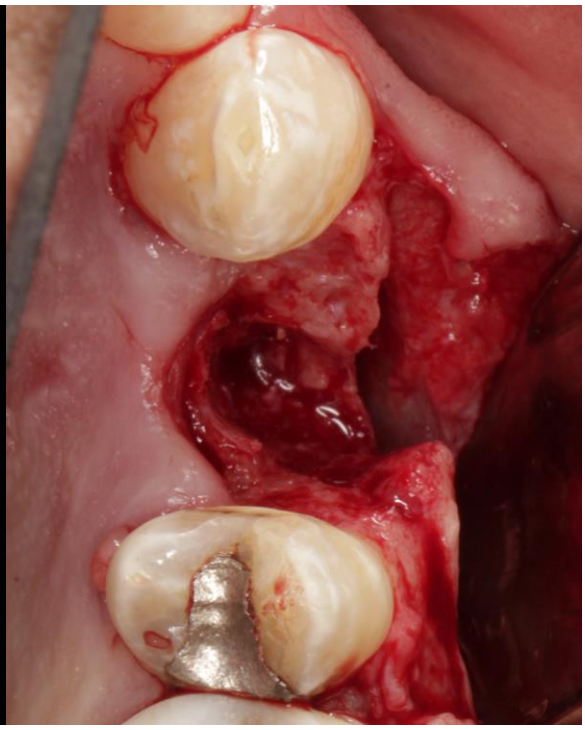


Flap reflection.

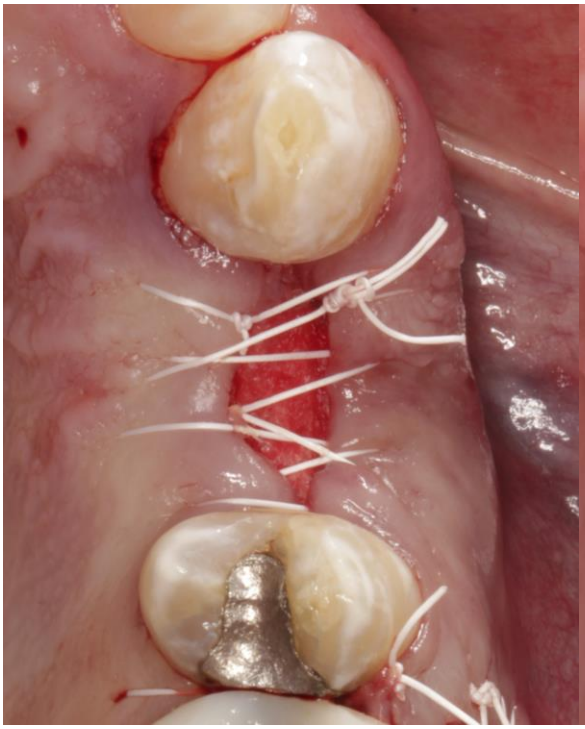


Severe early alveolar bone loss noted.

Implant explanted.



Residual alveolar defect.



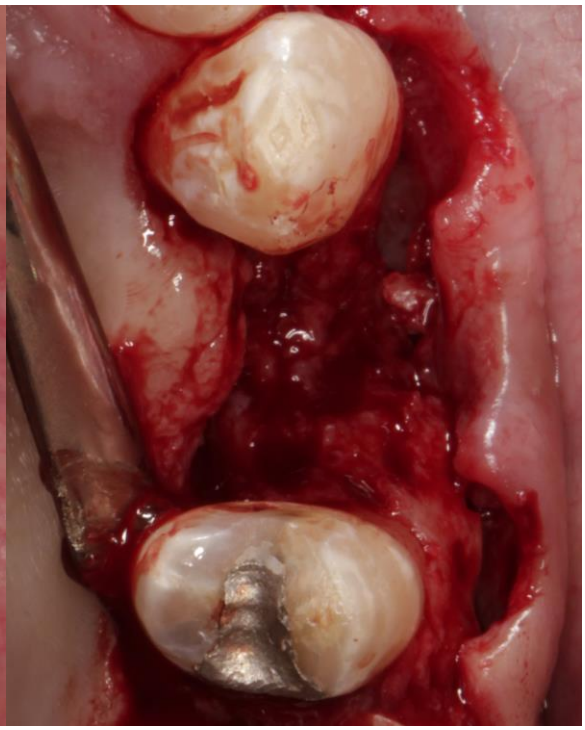
GBR completed.

Two weeks after GBR.

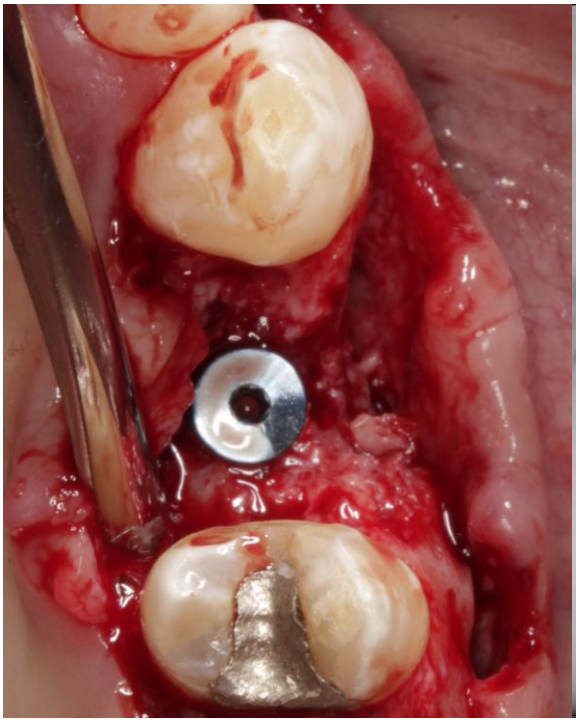
Four weeks after GBR.

Six weeks after GBR.

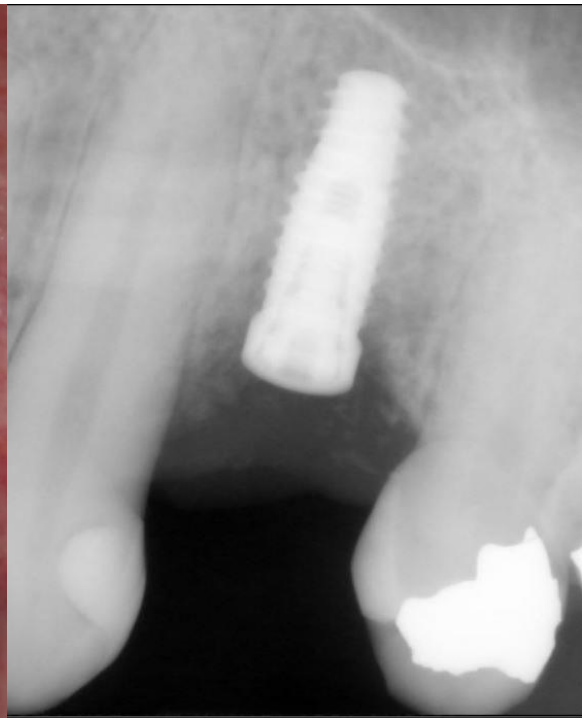
Ten weeks after GBR.



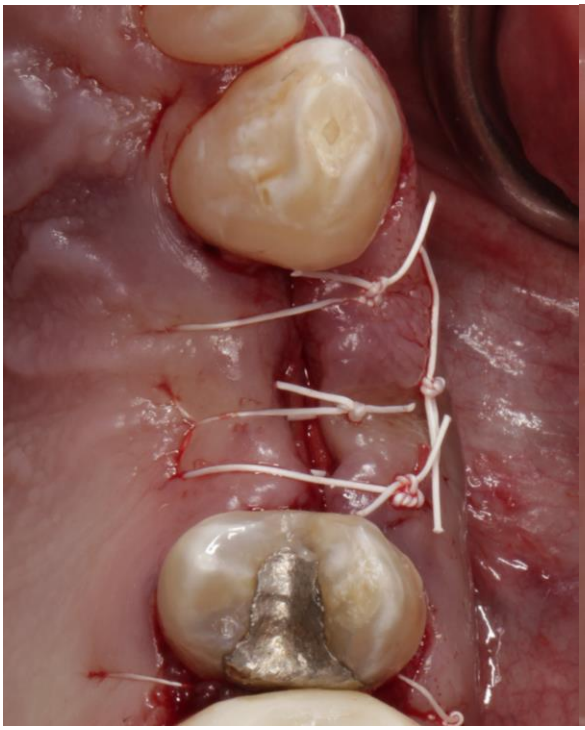
Three months after GBR



Implant #12 placed (second fixture).



Radiograph at implant surgery.



Closure following placement of FDBA and BioMend membrane.

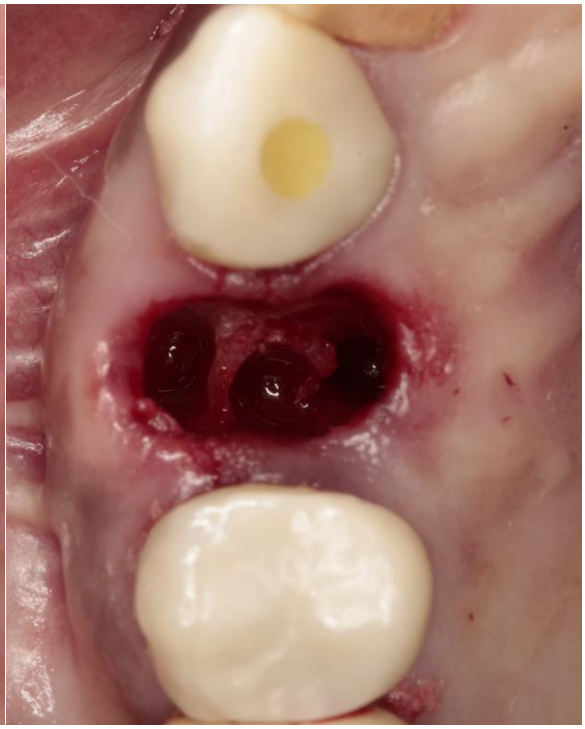
One week after implant with overlay graft.

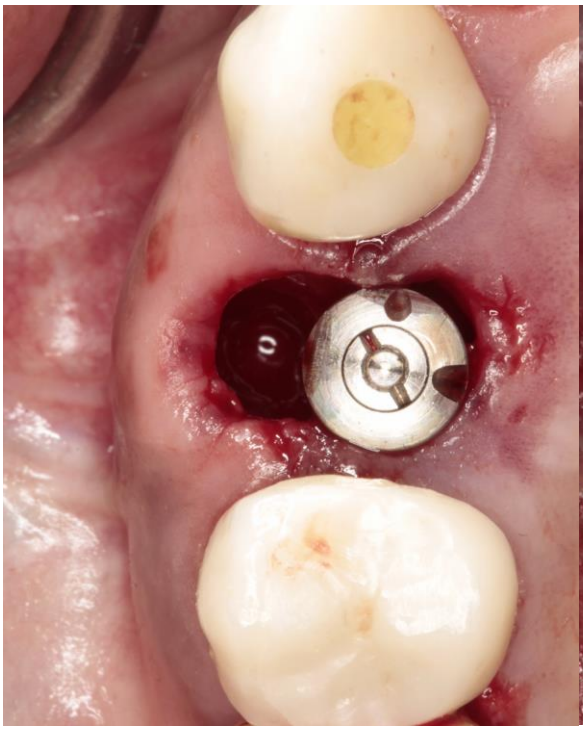
Two weeks after implant placement.

Three weeks after implant placement.

Case 14. Surgeon: CPT James Wilson **Date of surgery:** 3/27/2019
Diagnosis: Nonrestorable tooth #30 (insufficient remaining tooth structure)

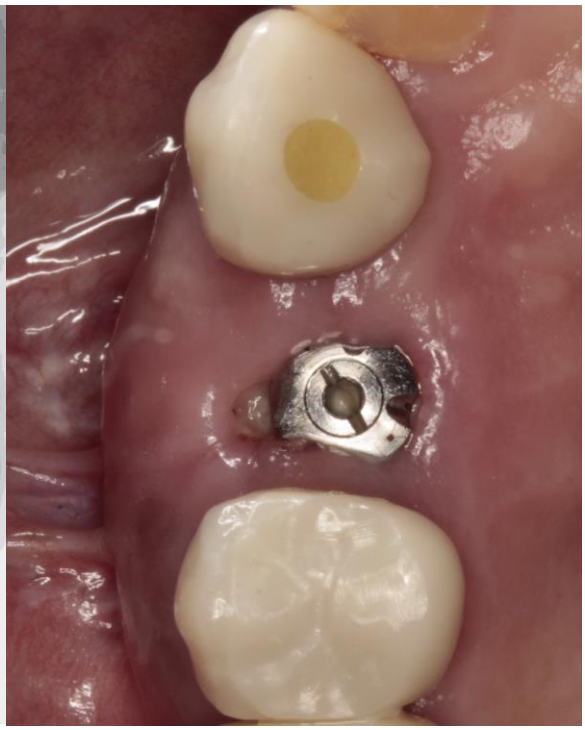

Baseline.


Minimally traumatic extraction.

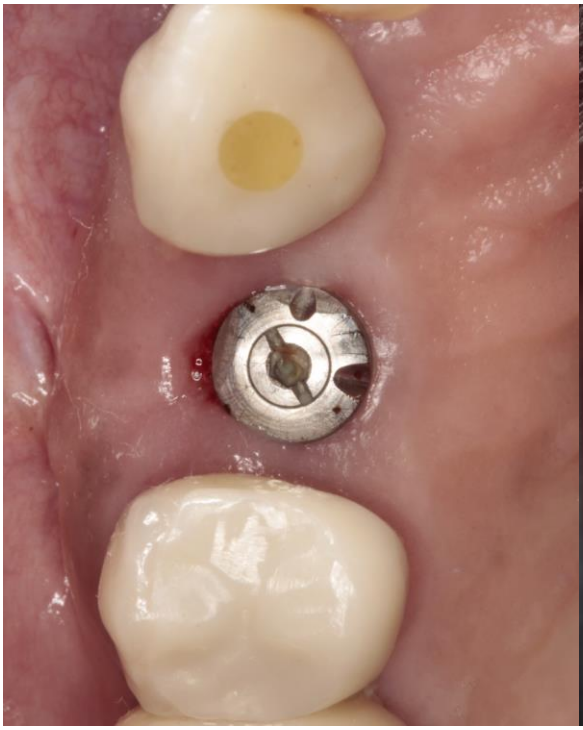

Implant placed.


FDBA placed, laser generated blood clot.

Radiograph at implant placement.

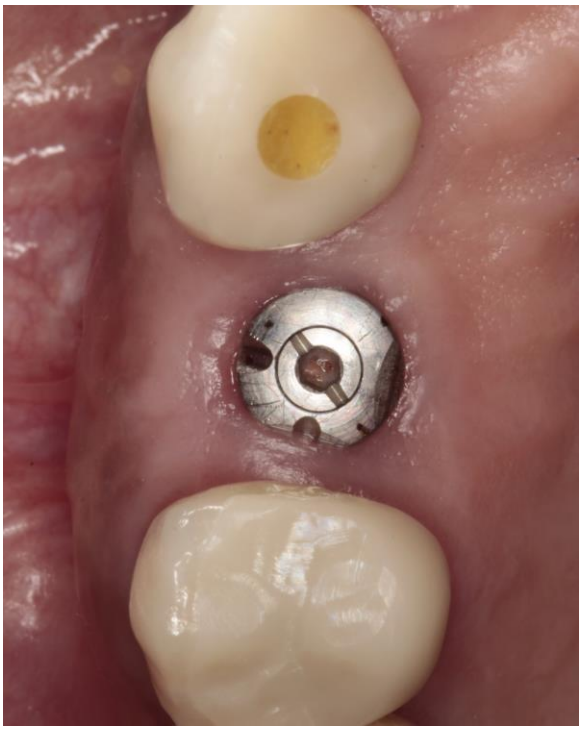


One week after implant placement.



One month after implant placement.

Three months after implant placement.



Six months after implant placement.