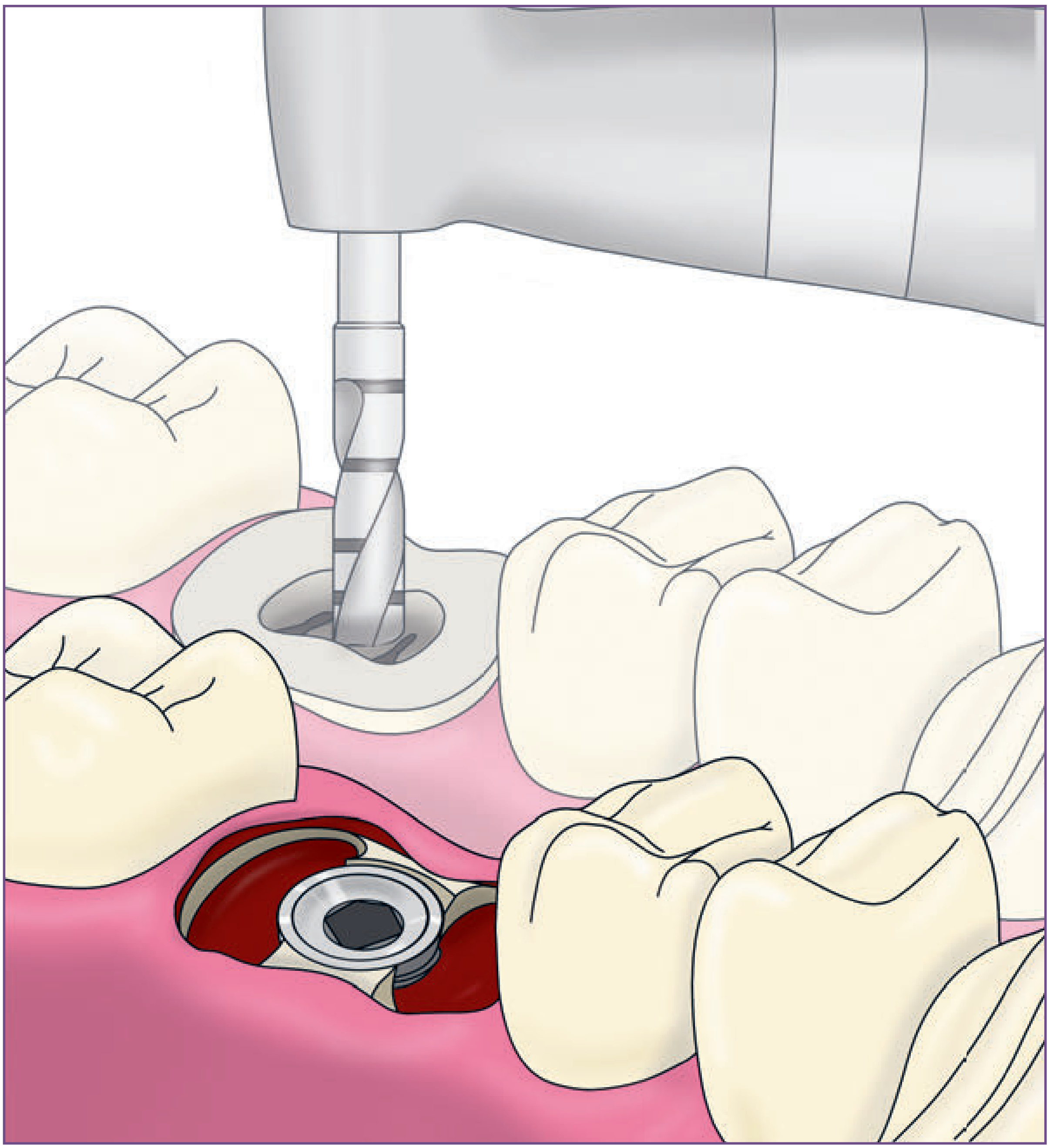
Dedication

Writing this book during a pandemic was a major challenge for us and our contributors, but we persisted. And what allowed us to remain optimistic was having the opportunity to interact with the very bright and talented graduate periodontic residents in both of our departments. It continues to be a humbling experience to interact with these outstanding young men and women, and it is to them that we dedicate this book.

Douglas Deporter & Mohammad Ketabi



IMMEDIATE MOLAR IMPLANTS

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PREFACE

It is not that people lose their dreams because they've grown old—rather, they've grown old because they have lost their dreams.

My coeditor for this book, Mohammad Ketabi, reached out to me over a decade ago asking if he could visit with me on sabbatical for 6 months, and when he did come, we immediately felt simpatico working together. So comfortable in fact that he has spent similar academic visits every few years since then. On his last visit, he suggested that we undertake a systematic review on immediate molar implant (IMI) treatment, which we did and published in 2016.[1] A second paper outlining suggested guidelines for successful outcomes with IMIs followed in 2017.[2] Both of these publications generated enormous interest from others worldwide, so much so that we decided to undertake the current book project. Mohammad already had considerable experience using and teaching IMI methodology in Iran and elsewhere.

Make no mistake: Treating patients with IMIs is no romp in the park. Like the late luminary P-I Brånemark who conceived osseointegration as a medical breakthrough, those who pioneered the use of IMIs clearly knew the importance of dreaming and encouraged the rest of us to do so too. One by one, small modifications in technique have led to big gains for patients in less than a generation. However, the procedures using IMIs require careful planning, preferably with the assistance of cone beam computed tomography, considerable skill, and a good working knowledge of anatomy and bone biology. Feeling comfortable with doing localized, indirect sinus floor elevations as originally proposed by Robert Summers[3,4] is also a prerequisite with undertaking maxillary molar IMIs. And, of course, using minimally invasive surgery and knowing when and how to use particulate bone graft materials and barriers and/or to undertake immediate nonocclusal loading are also critical.

There is no one way to do immediate molar implantation, as will be seen in this book. Differences among experts do exist, and those experts who have contributed to this book have made this clear. However, all agree that a molar implant should be placed ideally into the tooth's interradicular septal bone and initially stabilized by contact with the buccal and linguopalatal buttresses of bone. Gaps should always be left buccally to avoid any contact with the buccal plate, especially if the latter is thin, and while gap grafting may not be essential, the clinician must know when grafting is necessary to avoid unwanted local buccolingual/palatal shrinkage of the alveolar ridge, leading to crestal bone loss, gingival recession, unfavorable soft tissue coloration, and eventually implant hardware exposure.

I personally have learned a great deal from interacting with the experts who contributed to this book, as I believe you will as well. All of them were forthcoming and generous in sharing their experiences and knowledge, and all are still undertaking pioneering work on a day-to-day basis. Let's keep the dream going strong!

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ACKNOWLEDGMENTS

Compiling and editing a book for a highly regarded publisher like Quintessence is no small task, but their team made this second book with them a pleasant and rewarding experience. Despite delays due to COVID-19, the book Publishing Director, Bryn Grisham, was always supportive and understanding. In the end, this book project has kept me focused and (for the most part) sane during the coinciding unbelievably stressful pandemic that has interrupted all of our lives.

I also am truly grateful for the enthusiasm and support provided by our international group of contributors, each one a bright star helping us to unravel all the mysteries of immediate implant placement with or without immediate function. They have taken what seemed impossible and made it become reality. Everyone has been a privilege to work with, so generous with their knowledge and expertise and humble in their accomplishments. Thanks too to the graduate periodontic residents in our program at University of Toronto who were always keen to help, especially Drs Quang Nguyen and Ryan Noh. During the project, Ryan revealed that in addition to being a talented clinician, he is also a budding but already accomplished medical illustrator and offered his time and talent to do most of the illustrations in the book. The young people who we now receive in our training programs are truly gifted and a pleasure and honor to teach. I anticipate that many of them will contribute in a major way to the future of periodontics and implant dentistry.

Douglas Deporter

Special Thanks to Ryan Noh

Ryan Noh is currently enrolled in the Graduate Periodontic Program, Faculty of Dentistry, University of Toronto. Having been raised by parents who were both artists, he found a love of drawing at an early age. He worked selflessly and enthusiastically to create the majority of the artwork in this book, for which we are forever grateful. Hopefully, he learned a lot about immediate molar implants in the process.

During the past 20 years of my career as an academic, teacher, and practicing clinician, I have devoted much effort toward understanding, investigating, and applying the principles of implant dentistry. During this time, there have been so many changes and improvements in the field, but none more interesting and intellectually challenging for me and my colleagues and students than working toward the simplification and predictability of immediate molar implant (IMI) treatment.

From a patient's point of view, immediate implantation of any condemned tooth is perceived to be the most desirable treatment approach, as it requires the least time and least number of surgical interventions. As has been reported in multiple recent literature reviews, IMIs can have high survival rates, at least in the hands of experienced clinicians using well-defined protocols, and this book was conceived to bring together many of these internationally respected and acclaimed experts to share their hard-earned knowledge in using IMIs successfully.

Firstly, I especially want to thank my dear mentor, Prof Ali Akbar Khoshkhounejad, for his ongoing astute advice and generosity in sharing his extensive experiences with IMIs. Seeing and discussing with him his many remarkable clinical accomplishments was always an encouragement to me in bringing this book to completion. I also would like to thank Prof Moeintaghavi, Dr Ayobian, and Dr Nadaf for their ongoing encouragement and support.

I must confess that much of the work and difficulties encountered with this book project over the last 3 years of necessity had to fall on the shoulders of my coeditor, Prof Douglas Deporter, without whose diligence, hard work, expertise, and international connections, the task would have been impossible. In fact, our scientific collaborations and stimulating conversations over the past two decades have been for me a real privilege, pleasure, and treasure.

I present this book to all students, practicing clinicians, and dental academics interested in learning to excel in dental implant treatments, but especially to all the young, talented, and enthusiastic periodontic residents who have studied with me at the Islamic Azad University Dental School (Isfahan Branch), where I spent nearly 25 years of my life in different administrative and academic positions.

Last but not least, I dedicate this book to my wonderful family, Saeedeh, Shiva, Sara, and Mahdi, for their continuous support, encouragement, and understanding.

Mohammad Ketabi

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1

INTRODUCTION TO IMMEDIATE MOLAR TREATMENT OPTIONS

Douglas Deporter

The use of endosseous dental implants to replace missing or hopeless teeth has become routine practice in contemporary patient treatment. Indeed, implant-supported or implant-retained prostheses often are considered the treatment of first choice in both partial and complete edentulism because of their reported excellent long-term performance and patient satisfaction. Nevertheless, while treatment costs for a single implant-supported molar crown can be comparable to a three-unit, tooth-supported fixed partial denture, the longer treatment times and multiple interventions needed to complete the implant-based treatment do remain hurdles in gaining patient acceptance.[1,2] The original and well-tested principles of implant placement in healed extraction sites with a submerged initial healing interval continue to be used, and certainly molar replacement with single implants using this approach is reported to be predictably successful in the long term, particularly in the mandible and when natural teeth are present on either side of the implant.[3–8] However, the public is now aware of accelerated treatment approaches such as All-on-4 and "Teeth in a day" that provide immediate implant placement and immediate implant function. This awareness has fed the need to develop faster but equally successful treatment protocols for molar replacement. One such protocol is the replacement of condemned molar teeth using immediate implant placement with or without immediate function, and this book reviews the history, current status, technique prerequisites, and recent advances for this approach using a variety of implant types.

Timing of Implant Placement

Several classifications have been proposed to specify the timing of implant placement in relation to tooth extraction.[9–12] We have chosen the classification of Hämmerle et al,[11] which is based on the extent of both soft and hard

TABLE 1-1 Classification of timing of implant placement*

CLASSIFICATION	DEFINITION	ADVANTAGES	DISADVANTAGES
Type 1	Implant placement immediately following tooth extraction and as part of the same surgical procedure	• Reduced number of surgical procedures • Reduced overall treatment time • Optimal availability of existing bone	• Site morphology may complicate optimal placement and anchorage • Thin tissue biotype may compromise optimal outcome • Potential lack of keratinized mucosa for flap adaptation • Adjunctive surgical procedures may be required • Procedure is technique sensitive
Type 2	Complete soft tissue coverage of the socket (4–8 weeks)	• Increased soft tissue area and volume facilitates soft tissue flap management • Resolution of local pathology can be assessed	• Site morphology may complicate optimal placement and anchorage • Treatment time is increased • Socket walls exhibit varying amounts of resorption • Adjunctive surgical procedures may be required • Procedure is technique sensitive
Type 3	Substantial clinical and/or radiographic bone fill of the socket (12–16 weeks)	• Substantial bone fill of the socket facilitates implant placement • Mature soft tissues facilitate flap management	• Treatment time is increased • Adjunctive surgical procedures may be required • Socket walls exhibit varying amounts of resorption
Type 4	Healed site (> 16 weeks)	• Clinically healed ridge • Mature soft tissues facilitate flap management	• Treatment time is increased • Adjunctive surgical procedures may be required • Large variations are present in available bone volume

*Reprinted with permission from Hämmerle et al.[11]

tissue healing after tooth extraction. Hämmerle's type 1 sites are those where an implant is placed into a fresh extraction socket. Type 2 sites are referred to as *early* placement sites, ie, those where an implant is delayed until soft tissue closure over the extraction site has been achieved (typically 4 to 8 weeks). Type 3 sites are referred to as *delayed* implant placement sites, meaning those sites where substantial new bone formation has been allowed to happen before implant placement (typically 12 to 16 weeks). Finally, type 4 sites are those where the extraction sites have healed fully (ie, longer than 16 weeks), the tooth having been removed at some point in the distant past. The suggested advantages and disadvantages of the four types are summarized in Table 1-1.[11]

From the patient's point of view, type 1 implantation, ie, truly immediate, is the most desirable as it takes the least time and least number of surgical interventions to achieve. There are, however, technical challenges for the surgeon, such as avoiding bur chatter, controlling the final implant position, gaining sufficient primary stability, and maintaining and/or manipulating adequate soft tissue for appropriate site closure.[13] If the site has a thin gingival biotype preoperatively (ie, < 2-mm soft tissue thickness) and/or minimal keratinized gingival tissue (< 2-mm width), even if it is possible to stabilize an immediate molar implant (IMI), its health in the long term may be compromised because of an increased risk of peri-implant crestal bone loss needed to reestablish biologic width relative to implant type and placement depth.[14–20] Thus, van Eekeren et al[19] recently reported that gingival biotype had an impact on bone-level implant placement but not on tissue-level implant placement or when the implant-abutment connection was at least 2.5 mm above the crestal bone level. They suggested that when treating patients with initial mucosal thicknesses of 2 mm or less, choosing a tissue-level implant with the implant-abutment connection 2.5 mm above the crestal bone level for a posterior site (ie, esthetically less demanding) could help to minimize crestal bone loss. These considerations help to explain why IMIs are classified as being difficult and requiring considerable experience and ability of the surgeon.[21]

The decision to undertake early implantation (type 2, after 4 to 8 weeks of site healing) could be made for a variety of reasons, such as an existing acute local infection at extraction or a desire to permit some soft tissue healing and increases in amount and thickness of keratinized tissue before implant insertion. However, it needs to be remembered that some loss of alveolar ridge width and height will certainly have occurred, especially if a flap had been raised for the extraction, as most alveolar remodeling happens within the first 3 to 6 months postextraction.[22] Outcomes following early placement in various tooth sites can be comparable with those following immediate or delayed implant placement.[23,24] Early implant placement after a ridge preservation grafting procedure done at the time of extraction also may be a helpful protocol,[25] although it would add at least one extra surgical procedure. Most recently, however, it has been reported that early placement after extraction can give success rates similar to ridge preservation grafting and implant placement after 4 months of healing, at least at nonmolar sites.[26]

The benefits of waiting 12 to 16 weeks postextraction (type 3 sites) are that substantial new bone formation will have occurred within the socket and that the state of maturity of the gingival tissues will facilitate their manipulation. The disadvantages of this approach are again the loss in alveolar ridge dimensions, the longer treatment times, and the fact that additional surgical costs may be incurred. For example, it may become necessary to use commercial graft and barrier materials to thicken thin cortical bone buccally after osteotomy preparation, manage bony dehiscences, and/or regain local ridge anatomy to optimize patient comfort and prosthetic emergence profiles.

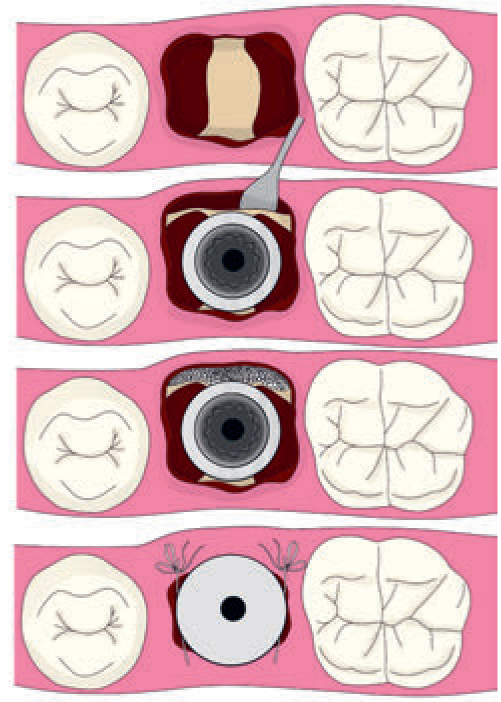


FIG 1-1 Buccal onlay grafting with xenograft can help to maintain alveolar ridge width. *(a)* Flapless surgery is used to remove a mandibular first molar revealing a type B interradicular septum (IRS) and an intact but thin (< 1.5 mm) buccal bone plate (see Box 1-1 for IRS classification). *(b)* A buccal full-thickness "pouch" was created using a small periosteal elevator. *(c)* Xenograft particles were packed into the pouch to reinforce the buccal bone. *(d)* The soft tissues were stabilized with sutures after placing a wide-diameter healing abutment.

Rationale and Early Work with IMIs

One of the original goals with immediate implant placement was that it would avoid or at least minimize the rapid alveolar ridge shrinkage that occurs both vertically and horizontally during normal extraction site healing. The greatest loss in alveolar ridge dimensions happens within the first 3 months postextraction, and by 1 year, buccolingual or buccopalatal ridge width shrinkage can be as high as 50%.[22,27] Worse still is the fact that the greatest loss in width happens midbuccally at the extraction socket, ie, exactly where the clinician wishes to locate an implant.[28] Looking at available human data, however, while losses in alveolar dimension can be reduced following immediate implant placement, they cannot be eliminated because many factors contribute to the losses.[29–33] Even when marginal bone gaps around immediate implants placed in molar extraction sites completely fill with new bone, resorption will still be seen on the external aspects of the associated ridge, particularly on the buccal.[29,34,35] Nevertheless, appropriate clinical management such as buccal particulate bone onlay/contour grafting can compensate for this thinning of buccal bone, provided that all socket walls remain intact following IMI placement[36,37] (Fig 1-1). If, as commonly happens, the buccal bony wall is missing or

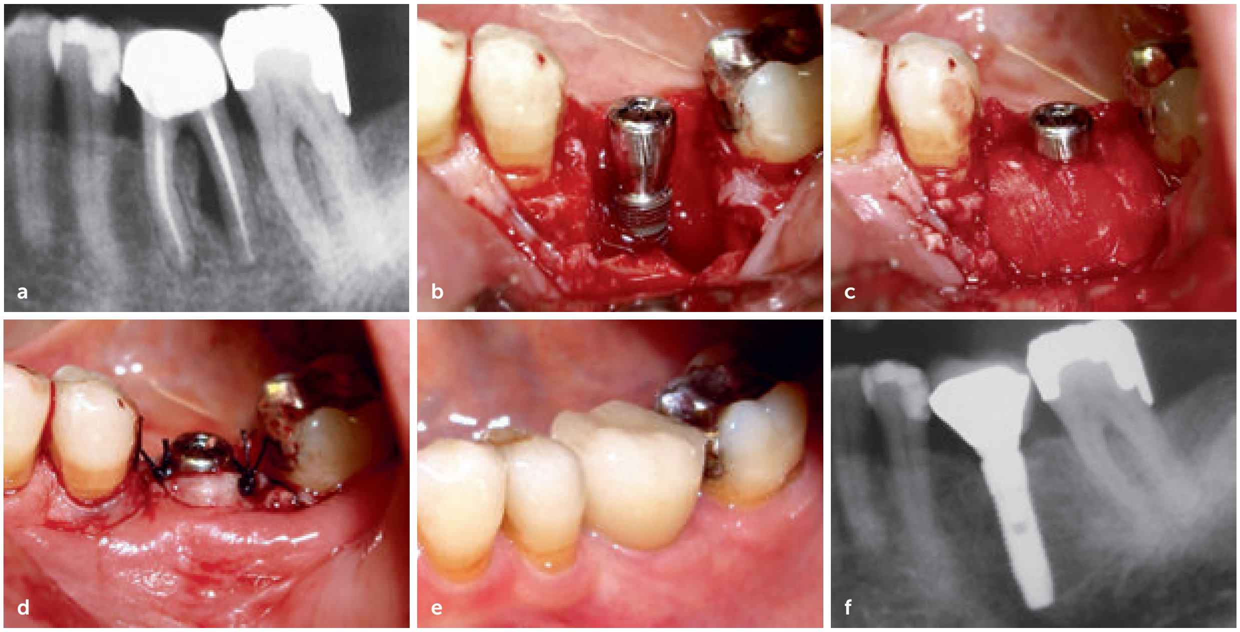


FIG 1-2 *(a)* The mandibular left first molar suffered failure of previous endodontic treatment and required extraction. *(b)* Flap elevation was needed to place this IMI, as the endodontic infection had caused considerable loss of buccal bone. However, the other three socket walls were intact and their crestal bone levels of sufficient height to suggest that GBR could be successful in restoring the lost buccal bone. *(c)* Because the IMI was well-stabilized, GBR (particulate allograft and collagen barrier) was used to promote regeneration of lost bone. *(d)* The immediate postoperative image of the implant site. *(e)* The clinical status of the restored IMI after 12 months in function. *(f)* The radiographic status of the IMI 12 months after the GBR procedure was performed. Note the excellent regeneration and stable crestal bone.

deficient, other treatment options can be chosen, the most common one being socket preservation grafting and delayed implant placement.[38]

Alternatively, if an IMI can be adequately stabilized, the deficiency often may be corrected with traditional guided bone regeneration (GBR) techniques[39] (Fig 1-2). One recent report claimed that—provided that flapless surgery was used to place IMIs at sites with buccal bone dehiscences (Elian type II sockets)—outcomes could have success similar to those with implants placed into intact sockets (Elian type I).[40] This was achieved by trimming and inserting a collagen membrane under the buccal soft tissue and densely packing xenograft into all defects around the seated implant, followed by placement of a healing abutment with a diameter corresponding to that of the extraction socket. The wide healing abutment will help to simulate primary soft tissue closure, sheltering the graft. Another group of investigators have since reported that densely packed xenograft alone can give the same benefit.[41] It was noted, however, that a healing interval of at least 6 months is needed to achieve favorable outcomes because xenograft has no known osteoinductive properties, and healing would be dependent on the response of osteoprogenitor cells of the periosteal layer of the buccal soft tissue.

While immediate implants were first used in the replacement of single-rooted teeth, innovators in implant dentistry were fast to translate the methodology to molar sites.[8,42–47] For example, Fugazzotto[45] described in detail an approach for placing immediate implants into the interradicular septum (IRS) bone of mandibular molars, focusing on ways to avoid bur chatter and drift (see chapter 3). He also reviewed the healing sequence following tooth extraction starting from clot formation. By 14 to 16 days, newly formed granulation tissue is replaced by connective tissue that subsequently converts to osteoid with calcification so that by 6 weeks, the socket is almost entirely filled with new trabecular bone. Fortunately, the placement of an immediate implant does not affect this normal healing sequence provided that the implant is sufficiently stable to avoid early micromovements.[48]

Fugazzotto further described protocols for maxillary IMIs[46] (see chapter 4). Osteotomy site location was first established in the IRS bone using a guide

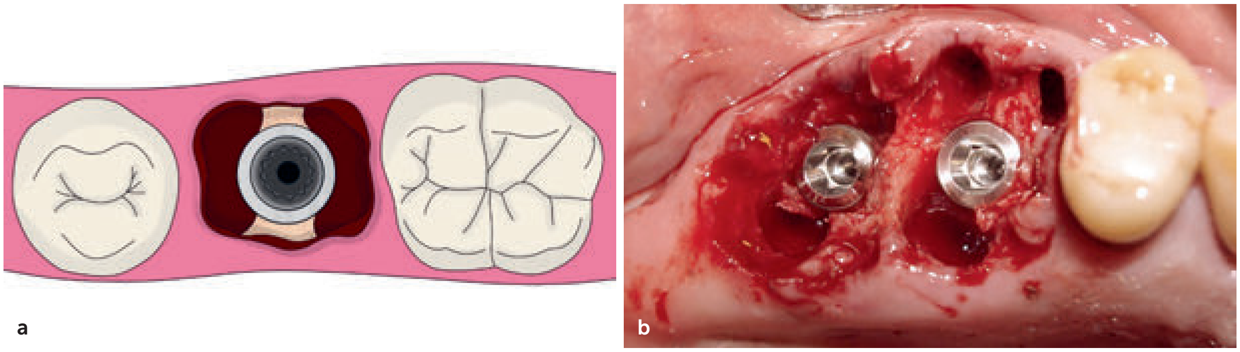


FIG 1-3 *(a)* An illustration of a site where an IMI could not be contained within IRS but was nevertheless stabilized by contact with the remaining lingual and buccal buttresses of the IRS. There is no actual contact between implant and buccal cortex, and the remaining peri-implant gaps have filled with blood and should heal with new bone fill provided that a large-diameter healing abutment will be added. *(b)* This first molar IMI was stabilized by the remaining buccal and palatal buttresses of a type B IRS.

drill, round bur, or narrow-diameter trephine, depending on the quantity of remaining apical bone. Thereafter, a series of handheld osteotomes of increasing diameter and a surgical mallet were used to finalize the osteotomy shape and depth as originally described by Summers.[49,50] Initial localization using a trephine was selected when there was insufficient remaining IRS bone height apically to receive the implant without disturbing the maxillary sinus. The trephine was used to create a core of IRS bone, taking care to stop short of the cortical sinus floor by about 1 mm. Thereafter, the core of bone released by the trephine was impacted apically with osteotomes to elevate the sinus floor. The safe insertion of a threaded implant could then be achieved. Others described a similar approach for maxillary first molars with 98% survival of implants at 3 years.[51] However, the recent introduction of the concept of osseodensification using Densah burs (Versah) for use in similar situations has eliminated the need for hammering on osteotomes, making placement of maxillary IMIs more patient-friendly[52] (see chapters 7 and 11).

Ideally, IMIs will be stabilized primarily either by being contained completely in IRS bone, or by contact with the remaining furcal bone buttresses located buccally and lingual/palatally without direct contact with the buccal and lingual/palatal socket walls (Fig 1-3). Unless these walls are very thick, insertion torque forces received by them could cause microfractures and early crestal bone loss. Any remaining gaps between the socket walls and implant periphery need not necessarily be grafted[34] (see also chapter 11) as long as the blood clots that have filled them can be sheltered by the repositioned flap margins in conjunction with appropriately sized healing abutments that can act as prosthetic sealing devices. More will be said of this later in this book.

When Immediate Molar Replacement Is Not Feasible

Before IMI therapy is proposed to a potential patient, the patient should be advised that the final decision on the feasibility of the approach cannot be made until after the tooth has been extracted. Factors such as root ankylosis, fracture of the buccal plate, unintended socket expansion during extraction, unexpected difficulty in tooth removal, or acute infection might make immediate implant placement impossible or less predictable. For example, if the extraction ends up being more traumatic than expected, requires elevation of a large mucoperiosteal flap, and/or results in significant loss of IRS and/or bone buccally or lingually/palatally, it may be necessary to delay implant placement and instead regain some of this lost bone using the techniques of socket preservation grafting.[53–56] There will always be value in using a flapless procedure to avoid disruption of the periosteal blood supply, but generally only if the original buccal bone at the crest has been determined to be intact.[55,57,58] Noteworthy is the fact that buccal bone loss after extraction has been reported to be significantly less if its original postextraction thickness was 3 mm rather than 1 mm.[59]

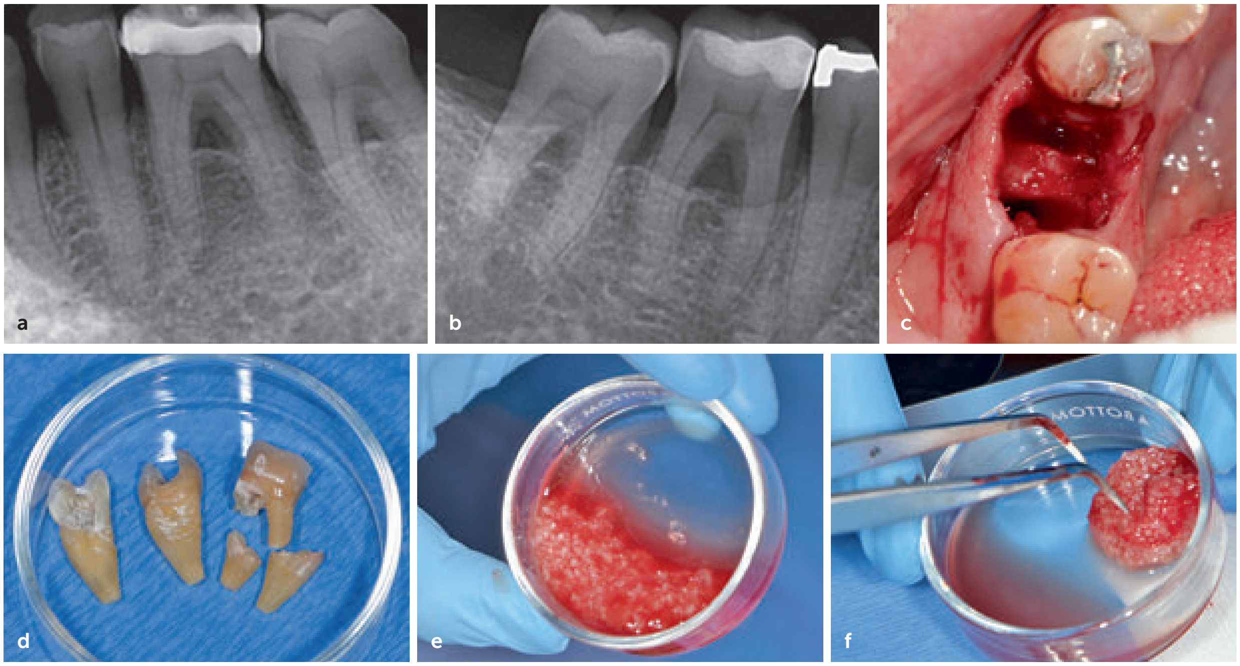


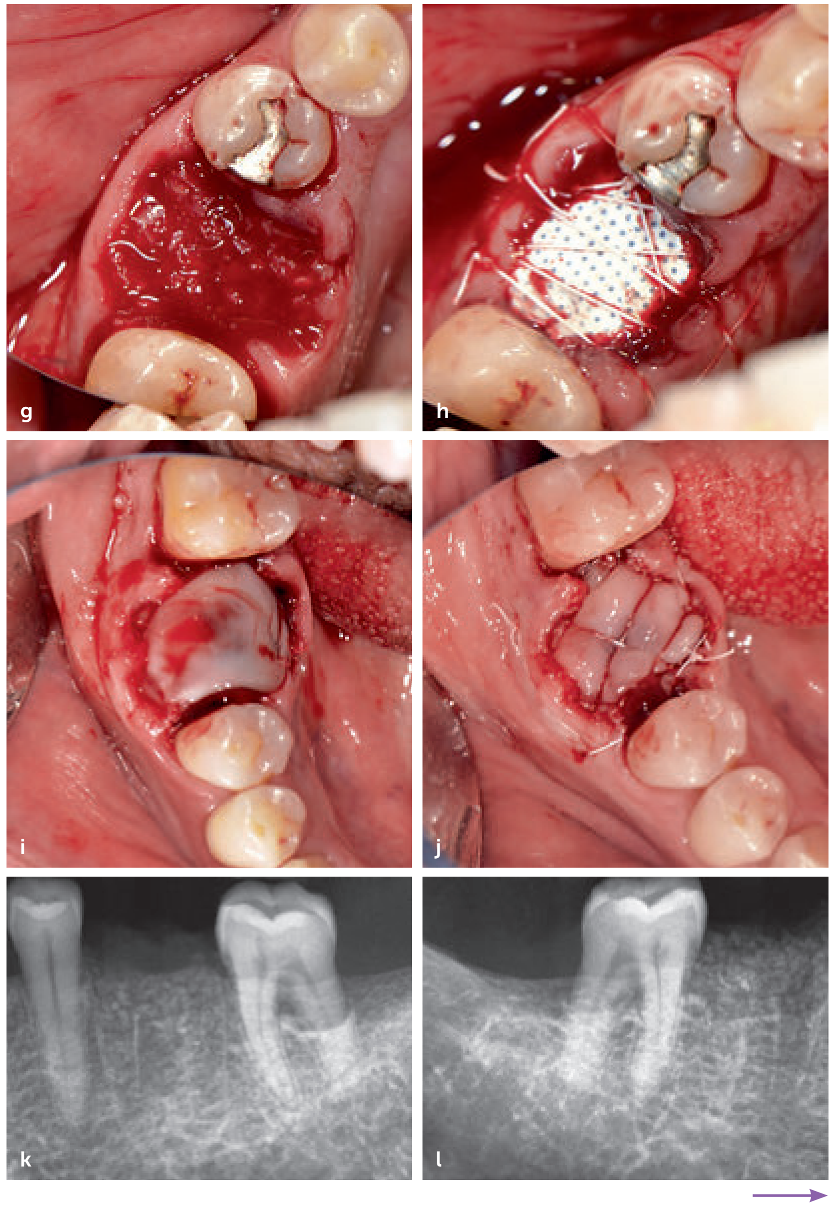
FIG 1-4 *(a)* The mandibular left first molar had a grade III furcation defect and was deemed hopeless in this man in his 50s who had insulin-dependent diabetes. *(b)* The mandibular right first molar in the same patient also required extraction. *(c)* The teeth were removed atraumatically without flap elevation after sectioning the roots through the furcation. The IRS for each of the teeth was classified as type B according to Smith and Tarnow.[67] (Surgery performed by Dr Suzette Guo, University of Toronto.) *(d)* The extracted tooth fragments are seen here after removal of all restorative materials as well as the pulpal and periodontal ligament soft tissues. *(e)* Once the tooth-derived particulate graft material was prepared using a dedicated processing machine, it was mixed with the liquid phase of platelet-rich concentrated growth factors (ie, autologous fibrin glue) obtained after centrifugation of a sample of the patient's venous blood in citrate-coated, white-capped plastic tubes as described by others.[63] *(f)* Mixing the patient's platelet growth factors and tooth graft particles resulted in a sticky pellet of tooth autograft biomaterial that could be easily used to fill the tooth sockets. →

If a flap is raised for tooth extraction and the socket deemed unsuitable for an IMI, the principles of GBR are followed for socket preservation, commonly using a particulate graft material (generally a mineralized allograft or xenograft) isolated and covered with a protective membrane and/or autologous platelet-rich fibrin (PRF) clots.[60–64] While the particulate graft material may delay socket healing somewhat,[38] it has generally been accepted that *(1)* grafting is beneficial in reducing alveolar ridge shrinkage, and *(2)* a mineralized slowly resorbing particulate graft material is preferred.[56] Ideally, a barrier material that can be left exposed crestally is preferred, as this will not deleteriously affect the anatomy of the buccal vestibule in any attempt to gain primary flap closure and will promote an increase in the quantity of keratinized tissue.[65,66] Examples of socket preservation using two different barrier approaches in a single patient can be seen in Fig 1-4.

Case report

As can be seen in Figs 1-4a and 1-4b, both the left and right mandibular first molars had grade III furcation defects and required extraction. The remaining IRS bone for both was classified as type B (ie, sufficient to stabilize an IMI),[67] which, under other circumstances, would have been favorable for IMI placement (Fig 1-4c). However, the patient had insulin-dependent diabetes with a history of severe periodontitis, and the clinician cautiously opted for socket preservation and delayed implant placement. Rather than using a commercially available allograft or xenograft, it was decided to process the extracted tooth fragments to form a genetically compatible particulate dentin graft (Fig 1-4d; see chapter 6). This was prepared using a dedicated processing machine (TOP Graft VacuaSonic System, CosmoBioMedicare). The more traditional approach would have been to use a mineralized particulate allograft or a xenograft like Bio-Oss (Geistlich).

FIG 1-4 *(cont) (g)* The sticky particulate tooth autograft was packed into the extraction site. *(h)* A double-barrier technique[68] was used at the left site to protect the particulate graft material: After first using a collagen barrier (Bio-Gide, Geistlich), a dense PTFE barrier (Cytoplast, Osteogenics) was trimmed appropriately, placed over the first barrier, and secured with sutures. *(i)* After atraumatic extraction and placement of the tooth-derived particulate autograft, the right site was covered with two autologous PRF clots[63] as the only barrier. *(j)* The right site covered with autologous fibrin clots was sutured, leaving the clots exposed. *(k)* The immediate postoperative radiograph of the grafted left molar site. *(l)* The immediate postoperative radiograph of the grafted right molar site.



After preparation, the dentin graft particles were mixed with autologous liquid fibrinogen isolated by centrifugation from the patient's venous blood to form the equivalent of "sticky bone"[63] (Figs 1-4e and 1-4f). Both sockets were filled with this graft preparation enriched by addition of the liquid fibrinogen and its platelet-derived growth factors (Fig 1-4g). The left grafted socket was covered with two barrier materials, first a resorbable collagen membrane and then a dense polytetrafluoroethylene (PTFE) nonresorbable barrier that was left exposed to the oral cavity[65,68] (Fig 1-4h). On the patient's right side, the grafted socket was covered with two PRF clots prepared from the patient's own blood[63] and again left exposed (Figs 1-4i and 1-4j). Immediate postoperative radiographs of the grafted sockets can be seen in Figs 1-4k and 1-4l.

Both sites healed well, resulting in sufficient bone at 4 months to allow single implant placement using a nonsubmerged technique and later restoration with single metal-ceramic crowns (Figs 1-4m to 1-4q). Because all particulate bone graft materials are known to interfere somewhat with normal extraction socket healing,[69] some clinicians have suggested an alternative approach using only autologous PRF clots to fill

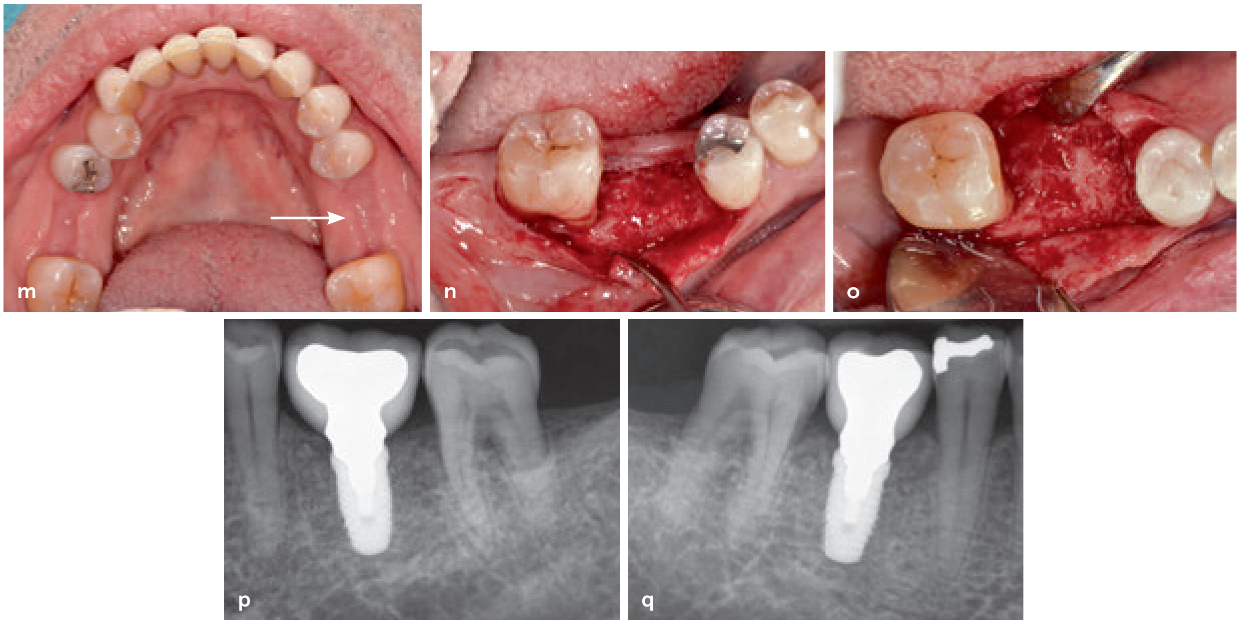


FIG 1-4 *(cont) (m)* A clinical photograph taken at the 6-week postoperative visit. Both molar sites appear to be healing well, but the patient reported having less discomfort at the side managed with the autologous fibrin clot barrier *(arrow)*. *(n)* A clinical photograph taken of the right side after 4 months of healing showing excellent new bone formation. *(o)* The contralateral site showing good site healing immediately before implant placement. *(p)* The restored left molar implant. *(q)* The restored right molar implant.

the socket.[70–72] One recent systematic review assessing the healing potential of a wide variety of grafting materials suggested that PRF was the most effective in promoting new vital bone formation.[73] However, another recent literature review with meta-analysis of published data using the latter approach suggested that more study is needed before routine usage can be prescribed.[74]

History of Immediate Molar Replacement

Early protocols for IMI placement provided scant details on procedural steps but led to acceptable outcomes for the time. In a small study published in 2000, Schwartz-Arad et al[75] reported outcomes for 56 IMIs placed in 43 patients during the period from 1989 to 1996. One implant was placed in 1989 and another 2 years later. This led to three IMIs being placed in 1993, 10 in 1994, 16 in 1995, and finally 23 in 1996, all by a single surgeon. In total, 17 IMIs were placed in maxillas and the remaining 39 in mandibles. If and how the procedure was modified over these 8 years was not indicated. Likewise, it was not stated whether there had been failed attempts in other patients. No criteria for patient selection were given, but it was reported that the majority of the implants had somehow been placed centrally in the molar sockets, while five molars had been replaced using two implants each, ie, one into each molar root socket. Implant lengths (10 to 14 mm) were chosen to engage as much apical bone as possible. Grafting of any peri-implant defects was done only at some sites, but indications were not given. The graft preferred was autogenous bone collected from implant burs or adjacent bone. Likewise, barriers were only occasionally used (six bioabsorbable collagen and two nonresorbable expanded PTFE, GORE-TEX, W. L. Gore) without explanation as to why the operator felt it necessary. Primary flap closure with the aid of releasing incisions was included where bone grafting and membranes had been used, but information was not given on how the remainder of the sites had been handled. Nevertheless, the 5-year cumulative survival rate was reported to be 89% (84% for men and 93.5% for women). Differences in outcomes also were found in maxilla versus mandible (82% vs 92% respectively) and with smoking (90% for nonsmokers vs 83% for smokers).

Fugazzotto[45,46] later described detailed protocols that he had developed for both mandibular and maxillary IMI placement. Osteotomies were created in suitable IRS bone, and all peri-implant gaps were grafted with xenograft particles covered with either titanium-reinforced ePTFE barriers or resorbable collagen barriers secured with tacks and followed by primary, tension-free soft tissue closure. As an aside, the problem with using GORE-TEX ePTFE barrier membranes was that great surgical skills and meticulous patient compliance were needed to achieve and maintain soft tissue closure over the site for the complete submerged implant healing interval. If the membranes became exposed by flap dehiscence at some point after placement, site infection was likely, meaning that the exposed barriers and infected graft material needed to be removed.[76] Depending on how long the barriers had been in place, their removal in itself could be traumatic and damaging to the site, compromising the outcome or resulting in early implant failure.

Wagenburg and Froum[44] presented their private practice outcomes with 261 IMIs in the mandible and 202 in the maxilla. In both arches, after decoronation and root removal, implants were placed slightly to the mesial of the IRS bone, most often utilizing a wide-diameter implant generally not in contact with the buccal and lingual/palatal plates of bone. Implants were placed 1 to 2 mm subcrestally. Mineralized freeze-dried bone allograft (FDBA) was tightly packed into peri-implant gaps, followed by placement of a Vicryl resorbable membrane (Ethicon) tucked under the flap margins. No attempt was made to advance the flaps to cover the membranes. Failure rates after at least 1 year in function were reported to be 4.98% in the mandible and 6.44% in the maxilla.

Recent years have seen publication of many more studies of IMI performance, along with recommended prerequisites for success. Assuming that intact socket walls remain, experts suggest flapless extraction and a thick gingival biotype as preferred, and that good initial implant stability (≥ 35 Ncm) is essential. Gap grafting and barrier materials are often considered optional, and implants can be left nonsubmerged for the initial osseointegration period, simplifying the procedure and shortening operating time. Wide-diameter healing abutments may be all that is needed to support the surrounding soft tissues, avoiding gap grafting and allowing healing by secondary intention (see chapters 3, 4, and 11).

Case Selection and Anatomical Considerations with IMI Placement

Contraindications

There are few patient contraindications when considering IMIs. Naturally, compliance with strict postoperative guidelines is essential, and ideally patients will be nonsmokers or minimal smokers, as smoking will negatively impact site healing.[77,78] Patients with a history of severe periodontitis (even if previously treated with apparent success) also may be at greater risk with immediate implants, especially in maxillary sites and with time in function.[79–82] As well, patients currently taking oral bisphosphonate medications or who have previously taken them for more than a few years will likely be at greater risk of complications and implant failure.[83] One way to reduce risks here is to prepare the extraction sockets with PRF clots immediately before implant insertion.[84] Other patients who may not be appropriate are those with uncontrolled diabetes,[85] those with a history of head and neck radiation in the previous 12 to 24 months,[86] those who are currently taking receptor activator of nuclear factor kappa-B ligand (RANKL)-inhibiting anticancer drugs,[87] and those who have a history of bruxism[88] or other parafunctional habits.

It is also worth determining if the patient is vitamin D and/or magnesium deficient before undertaking treatment, especially in older individuals.[89,90] Kim et al[91] recently reported a link between low serum 25-hydroxyvitamin D [25-(OH)D] levels, tooth loss, and prevalence of severe periodontitis in South Koreans aged 50 years and older. It has been reported that vitamin D deficiency reduces host resistance to infection in orthopedic joint replacement procedures. Serum 25-(OH)D levels of 109 patients scheduled to receive a total prosthesis either of the hip, knee, or shoulder were measured after admission to the hospital.[92] Serum 25-(OH)D levels were also measured for patients presenting with periprosthetic joint infection (n = 50) or aseptic loosening of the prosthesis (n = 31) who were scheduled to undergo revision surgery. Significant differences in 25-(OH)D levels were found when comparing patients with periprosthetic joint infection and patients scheduled for primary arthroplasty ($P < .001$). A significant difference ($P < .001$) was also found when comparing patients with periprosthetic joint infections to those with aseptic prosthesis loosening. Accordingly, investigators suggested single-dose preoperative vitamin D supplementation prior to joint prosthesis surgery.[93]

Others have studied the impact of vitamin D deficiency on the integration of titanium alloy implants in rat femurs.[94] Implants were surface-modified either with double acid etching or with double acid etching followed by discrete crystalline deposition of hydroxyapatite nanoparticles. After 14 days of site healing, implants placed in vitamin D–deficient rats showed significantly weaker integration than those implanted in control animals. Others studied the impact of implant integration in tibias of ovariectomized rats.[95] One group of rats was fed a vitamin D–free diet for 8 weeks, while a second group was fed the same diet for 6 weeks followed by a standard diet containing 2,400 IU/kg of vitamin D for the last 2 weeks of implant site healing. Finally, a control group of normal rats was fed the latter diet for the full 8 weeks. Results showed a significant decrease in cortical bone-to-implant contact in the D-deficient group only. No detectable effect of vitamin D deficiency was observed in cancellous bone.

Site selection

The key to success with IMIs, of course, is careful site selection,[77,96] and more will be said of this in the following chapters. It must be emphasized that the recommended procedures are certainly technique sensitive and—like short implants—may not be appropriate for clinicians who attempt the procedures infrequently.[97] Local hard and soft tissue conditions including gingival biotype and socket anatomy must always be considered. For example, sites with a thin gingival biotype (ie, a periodontal probe inserted into the gingival crevice can been seen through the overlying tissue) and/or a thin (< 1.5 mm) and/or compromised buccal bone plate may not be good candidates or may require more complicated procedures, including GBR. A pretreatment CBCT scan is essential to allow assessment of root positions and shapes, the anatomy of remaining IRS, and the presence of intact buccal and lingual/palatal cortical plates along with their thicknesses (see chapter 2). Pretreatment CBCT scans also allow a risk assessment regarding potential damage to neurovascular structures[96] and/or perforation of the lingual cortical plate in the mandible.[98] In the maxilla, pretreatment CBCT records will provide useful information about sinus proximity, intrusion of maxillary molar roots into the sinus, current alveolar ridge dimensions, and furcal roof distance from the sinus floor.

Extraction technique and osteotomy preparation

Of utmost importance with an IMI procedure is the careful, atraumatic removal of the condemned tooth. The ideal approach is to perform the extraction without raising a mucoperiosteal flap in order to minimize disruption to local blood supply and help to minimize loss in alveolar ridge width.[55,99,100] However, initial buccal bone thickness again comes into play as well because even with flapless surgery, greater buccal bone loss will occur if its initial thickness was less than 1.5 mm.[101] Leaving a significant (> 1 mm) buccal implant-to-bone gap with or without grafting also will help to stabilize the buccal crest as new vital bone forms in this gap[31,102] (Fig 1-5).

If a flapless technique is feasible, after making conservative intrasulcular incisions, the molar is first decoronized using a fissure bur and high-speed handpiece. Thereafter, the roots are sectioned free with the same bur so as to permit their removal individually using small-tipped elevators and/or periotomes[103] (Fig 1-6). A very helpful tool is a thin, long, high-speed diamond bur inserted into the ligament spaces where needed to create narrow channels into which a small elevator or periotome subsequently can be inserted and used to loosen the individual roots (Fig 1-7). This bur should be used to remove tooth structure rather than bone and reach a depth of at least two-thirds the root length, by which time the root fragments should be easily removed. Wang et al[104] discussed the use of periotomes, suggesting that the first step should be to use a 15c blade supracrestally to release the gingival fibers from the tooth. Afterward, a thin periotome can be placed subcrestally to widen the periodontal ligament spaces circumferentially but primarily at proximal surfaces so as to minimize damage to buccal bone. Again, using a thin diamond pencil-type bur and a high-speed handpiece could minimize any

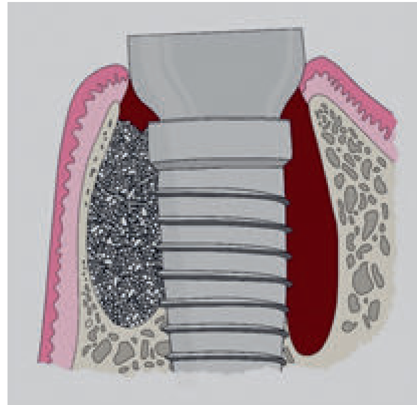


FIG 1-5 If an IMI can be stabilized in IRS of a molar socket having a thin (≤ 1.5 mm) buccal cortical plate of bone, a buccal gap should be left and most likely grafted in order to prevent significant vertical resorption of this cortex and significant loss in buccolingual ridge width. In this illustration, the lingual gap was left ungrafted as it would fill with a blood clot, which, if sheltered by a healing abutment, would lead to new bone formation and gap fill.

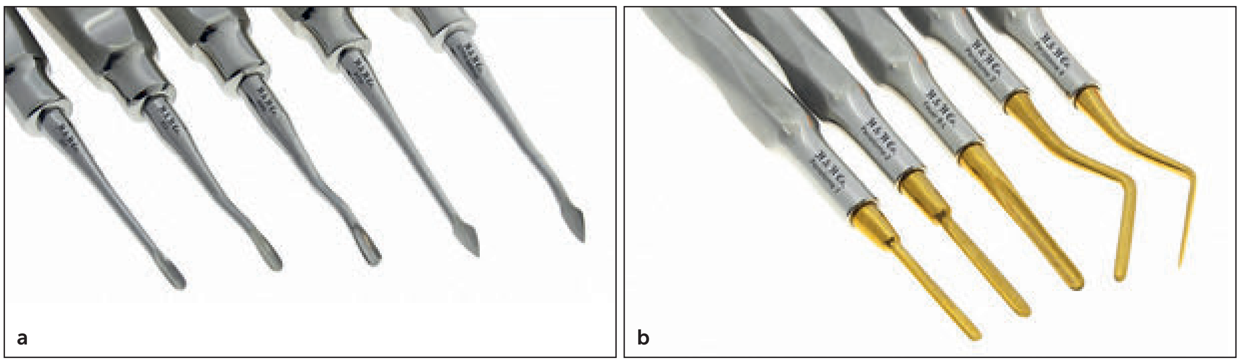


FIG 1-6 *(a)* Examples of fine-tipped surgical elevators useful for loosening molar roots after decoronation and sectioning. *(b)* Samples of periotome tips useful for luxating separated molar roots prior to their removal.

FIG 1-7 A long, small-diameter high-speed diamond bur can be used to create narrow channels in the periodontal ligament spaces of the molar roots prior to using thin luxators/elevators or periotomes to avulse the roots individually. The penetration depth of the bur should be at least two-thirds of the tooth root length to reduce the risk of root fracture during subsequent luxation/removal. Normally, use of this bur should be limited to the proximal root surfaces so as not to damage the IRS or thin cortical plates. The bur shown in this photograph is an FGSurg Medium Needle Diamond bur #859.36.10 (Brasseler).

periotome-related bone damage as well as shorten the time required for the procedure. Progressively larger periotomes are used to further loosen each root and permit its removal with root forceps.

As stated earlier, optimal placement of an IMI generally will be into the IRS. Smith and Tarnow[67] classified molar socket IRS into three groups (Box 1-1). Type A were denoted as those with sufficient volume to contain the whole coronal periphery of the selected implant, while type B were those with sufficient volume to stabilize the implant but with dehiscences in the IRS after osteotomy preparation at one or more aspects of the implant. With either of these IRS situations, it may be wise to leave the osteotomy one size smaller in diameter than the intended final implant bur to ensure adequate implant stability (ie, ≥ 35 Ncm). Achieving adequate implant stability, particularly with type B situations, may require engaging

BOX 1-1 Smith and Tarnow classification of molar extraction sites for immediate implant placement[67]

Type A	Adequate septal bone to circumferentially contain the coronal portion of the implant within the bone completely
Type B	Enough septal bone to stabilize the implant but not fully contain it, leaving gaps between one or more surfaces of the implant and the socket walls
Type C	Not enough bone within the socket to stabilize the implant without engaging the outer walls of the socket

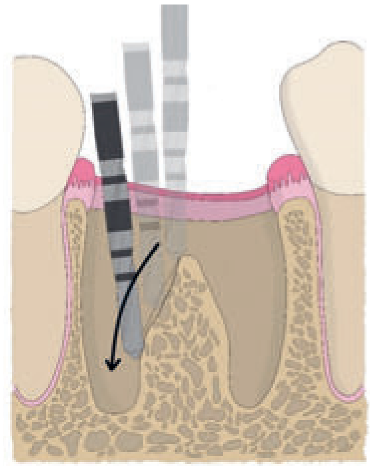


FIG 1-8 If osteotomy preparation is undertaken after removal of both roots, it is often difficult to stabilize the initial burs within the IRS, with the result that bur slippage may damage the IRS.

3 to 5 mm of bone apical to the IRS.[105] Optimal 3D positioning also dictates IMI placement 2 to 3 mm below the gingival margins of adjacent teeth, greater than 2 mm away from the buccal cortical bone plate—particularly if it is thin—and 1.5 to 4 mm away from any adjacent teeth. Subcrestal implant positioning has also been recommended for particular implant designs,[106–109] as this too will help to compensate for any untoward vertical loss in crestal bone height during initial site healing.

The problem with removing tooth roots before starting osteotomy preparation is that it can be difficult to control the burs, which in a type B IRS can easily slip into one or other of the tooth root sockets (Fig 1-8). As a result, most clinicians now agree that initial implant osteotomy preparation for an IMI is best begun before removing the tooth roots. Their recommendation is that after decoronation and before sectioning of the molar roots, a high-speed handpiece and round bur be used to begin the osteotomy directly into the furcation area of the tooth and underlying bone. This will provide anatomical guidance and stability for effective bur function. Once into bone, and provided that the subsequent burs will not be in direct contact with the remaining tooth structure causing chatter, a pilot bur followed by the dedicated implant burs can be used to partly or completely finish the osteotomy before sectioning and removing the individual roots. This technique was pioneered by individuals such as Rodriguez-Tizcareño[110] and others.[111,112] One recent publication compared this approach to the situation where roots were removed before osteotomy preparation, and found the former approach to give better outcomes in terms of ideal implant location and stability.[112]

Specific implant design features for IMIs

The greatest concern with the placement of IMIs is being able to achieve adequate primary stability in a prosthetically favorable location, ie, often centrally in the IRS. Initially, IMI placement relied on modifying existing surgical techniques[45] to accommodate standard implant designs, and certainly the introduction of osseodensification burs to expand and sculpt IRS bone has been an important advancement[113] (see chapter 7). Manufacturers have also introduced implants with more aggressive threads to help with initial implant stabilization.[114] Others have proposed the use of ultra-wide (≥ 6-mm diameter) implants relying on engagement of any buccal and lingual/palatal bone struts for implant stabilization[108] (see Fig 1-3 and chapter 8). Wider-diameter implants offer the advantage of increased bone-to-implant contact, less coronal stress in molar sites with their heavy occlusal loading, and as a result, less crestal bone loss. They also provide prosthetic platforms that permit more natural molar implant crown profiles and emergence profiles. Disadvantages include possible excessive torque in the posterior mandible during insertion and violating the buccal plate if the implant periphery contacts it.

Making a decision regarding appropriate implant diameter should be based on the following considerations:

- Mesiodistal ridge width[115]
- Type of IRS
- Subantral bone height (in the maxilla)

In regard to types A and B IRS, the usual diameter chosen will likely be 4 to 5 mm. Diameters greater than 5 mm may be appropriate for type C septa, large mesiodistal ridge lengths, and limited subantral bone height where sinus floor elevation is contraindicated as part of IMI insertion. Tapered implant shapes also may help to improve initial implant stability.[116]

Managing gingival biotype with IMIs

As already stated, with bone-level implant designs, thin gingival biotype may affect treatment outcomes by predisposing to unwanted crestal bone loss needed for biologic width accommodation and increasing risk of both peri-implant mucositis and peri-implantitis, particularly if buccal bone thickness also is an issue.[15,117–122] Placing implants subcrestally along with the use of longer healing abutments at sites with a thin gingival biotype may help in reducing crestal bone loss.[123] Platform switching also appears to be of benefit in reducing bone loss, while also promoting thicker buccal soft tissues with less likelihood for recession.[124–126] However, if the clinician wishes to minimize untoward effects on crestal bone at sites with a thin gingival biotype, soft tissue grafting to increase the peri-implant keratinized tissues may be the best option. Grafting with autologous connective tissue taken from the patient's palate or tuberosity (or if need be with free gingival grafts) generally has been regarded as the gold standard approach, although commercially available collagen matrix products also have been used.[127–131] Timing for undertaking this grafting appears not to be crucial, as it can be done before or at the time of implant placement or even later if need be.[132]

Gap grafting and wound closure

As discussed earlier, when IMI protocols were originally conceived, it was felt that any socket spaces or gaps that remained after implant insertion needed to be managed with some sort of mineralized particulate graft[56] covered with a resorbable or nonresorbable barrier material and submerged under a mucoperiosteal flap released sufficiently to allow tension-free complete wound closure. This added to the time involved for the procedure, its difficulty and cost, unfavorable alterations of the associated vestibule, and the risk of postoperative complications. Supported by more recent findings, most clinicians now prefer to simplify the procedure by allowing nonsubmerged healing of IMIs, often with little or no gap grafting.[133] Gap grafting at IMI sites may help to protect thin cortical bone, particularly on the crucial buccal aspect[34,134] (see Fig 1-5). However, it is unlikely to totally eliminate vertical crestal bone loss, especially if a flap has been raised for the procedure, making it important to place the implant 1 to 2 mm subcrestally.

Clinicians should avoid the trap of choosing implant diameters that will obliterate any buccal gaps (gap type 2 of Deporter et al[135]) because this could apply unwanted pressure on the buccal wall and likely encourage its resorption. While experts do vary in their choice of a crucial gap size requiring grafting, most feel that, provided the IMI is adequately stabilized, gaps less than 3 mm and certainly less than 2 mm in width should not need grafting. More recently, experienced clinicians have suggested and documented that gaps need no grafting regardless of their size[136] (see chapter 11). Using a wide-diameter healing abutment as sold or customized (see also chapter 12) or placing an immediate provisional crown can be used to support repositioned soft tissues and shield any gaps that have spontaneously filled with blood.[137–140] Using a healing abutment or immediate provisional crown will also provide some early nonocclusal loading, favorably influencing bone healing.[141] Additional advantages here would be the ability to add and subtract material for gingival support and contouring during the osseointegration phase.

Finally is the matter of how to manage the soft tissues following IMI placement without flap elevation if no gap grafting is done. Clinicians have taken

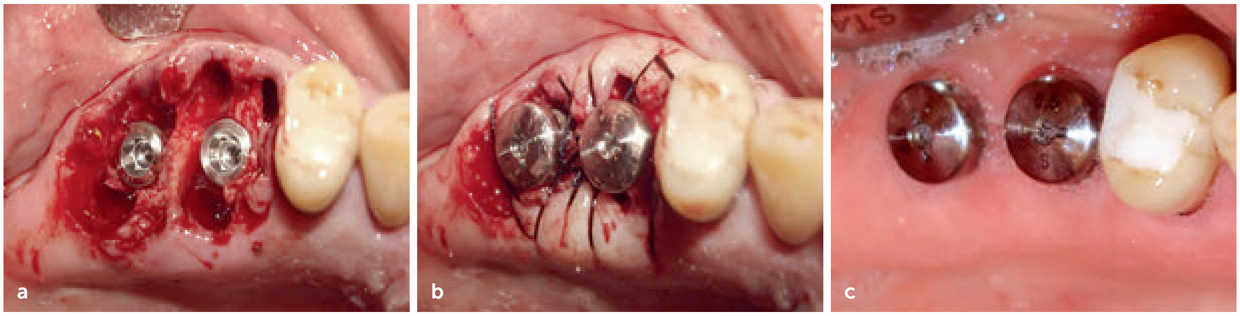


FIG 1-9 *(a)* After placing these two IMIs, large ungrafted gaps remained buccally and palatally. *(b)* Wide-diameter healing abutments were inserted and the soft tissues repositioned and passively sutured. *(c)* The site after 3 months of healing.

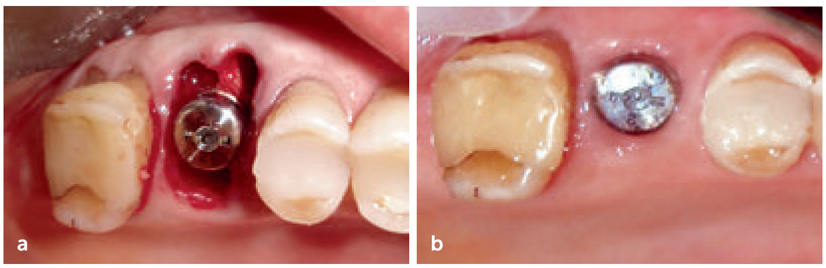


FIG 1-10 *(a)* Following flapless surgery and implant placement, the gaps remaining around this IMI were left without grafting or suturing. *(b)* Spontaneous bone fill and soft tissue healing occurred without complication.

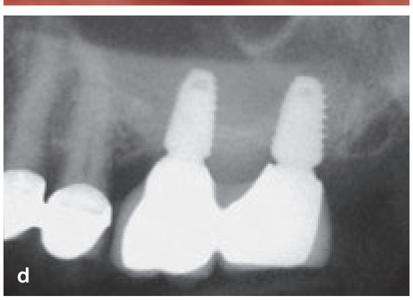


FIG 1-11 *(a)* These two IMIs were left without healing abutments, without grafting, and without suturing after inserting healing caps only. *(b)* The large gaps filled in with granulation tissue. *(c)* After 3 months of healing and re-entry surgery, the implants were ready for restoration. *(d)* The posttreatment radiograph after 12 months of implant function.

various approaches. As already stated, the most common approach is to add a wide-diameter healing abutment and passively suture the soft tissues around it (Fig 1-9). Others prefer not even to suture, leaving the gaps exposed because there are no graft particles that could be lost (Figs 1-10 and 1-11). At the opposite extreme, releasing incisions can be made to help with some flap advancement (Fig 1-12). Some clinicians prefer to cover the whole site with a free gingival graft (previously coined a "socket seal"), a resorbable or nonresorbable barrier or collagen plug, or autologous PRF clots[142–148] (Figs 1-13 to 1-15). In the final analysis, soft tissue coverage following IMI placement without gap grafting seems not to be an issue.