Single-Implant Complications

Biomechanics, Incidence, and Prevention

Charles J. Goodacre, DDS, MSD
W. Patrick Naylor, DDS, MPH, MS

QUINTESSENCE PUBLISHING

Single-Implant Complications: *Biomechanics, Incidence, and Prevention*

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Dedications

To my wife, Ruthy (Goodacre), for her unwavering support and always positive personality. Without her at my side, I would not have been able to make this contribution to prosthodontics, nor the others that have occurred during my career.
– CJG

To my wife, Pennie (Naylor), for her patience and understanding during the many months devoted to this book, and her shared commitment to this contribution to the dental literature.
– WPN

Contents

Foreword

It is tempting to regard the first published book on osseointegration (OI) in 1985 as canonical. It ushered in a new, exciting era for diverse clinical approaches to managing tooth loss, which rapidly catalyzed additional research, scientifically based clinical developments, and new organizational initiatives devoted to its application. But it was Quintessence International that had the vision to launch a continuum of published scholarship in the field to ensure fulfilment of OI's educational mandate and global reach.

Per-Ingvar Brånemark's serendipitous observation/finding that a commercially pure titanium chamber used for studying in vivo blood flow in bone could not be separated from its host tissue launched his resolve to develop human clinical applications from his observations. What started as a proposed and scientifically viable solution for the edentulous predicament quickly evolved into an impressive range of clinical solutions for various tooth loss challenges.

It should also be readily acknowledged that Brånemark was indeed lucky to have the veracity of his biologic observation and early clinical research translated into both more surgical and prosthodontic initiatives by numerous clinical scholars, along with newly motivated authors from the global dental community, especially Drs Charles Goodacre and Patrick Naylor. Their much-respected clinical expertise in traditional recruitment of crown and bridge protocols to ensure functional and esthetic restoration of individual missing teeth was reflected in their teaching commitments and publications throughout their academic careers—and well before OI opened the door to a new era of clinical management. They were also among the first to acknowledge the ecologic merits of a minimally intrusive therapeutic intervention that did not rely on removal of enamel on adjacent teeth—a first for a profession that somewhat belatedly came to terms with the reality that enamel is a nonrenewable resource!

Drs Charles Goodacre and Patrick Naylor have now focused their combined scholarship on a critical appraisal, indeed understanding, of the unique biomechanical features that must be understood to fulfil OI's applied promise for single-tooth replacement. They have also made us realize that their robust analysis of individual implant loading lends itself to equally fascinating collective loading considerations when planning multi-implant restorations.

This text is a compelling explanation of how prosthodontic treatment can be planned to ensure both efficacy and effectiveness of specific and scrupulously planned single-tooth implant replacement interventions. The OI technique has led to compelling new initiatives for the entire oral rehabilitation scenario, and this text's authorship provides exemplary scholarly focus on one of the most brilliant applications of Brånemark's research—replacement of the missing single tooth.

This is a thoroughly stimulating and informative book that deserves to be read by the entire dental profession.

George A. Zarb, BChD, MS, DDS, MS, FRCD
Professor Emeritus, University of Toronto

Preface

Single-implant treatment has become an integral component of oral care provided in a wide range of clinical settings—from solo dental practitioner offices to multispecialty group practices. While some clinicians may limit the scope of their services to focus primarily on implant surgical placement or restoration, others choose to offer comprehensive treatment planning along with implant surgery *and* restorative dentistry in the same setting. Regardless of who does what and where, the clinical outcomes can be both transformative and life-changing.

The *transformative* phase was recognized early on with the replacement of a conventional three-unit fixed partial denture (supported by two teeth) with a single implant and crown in the edentulous area. The *life-changing* aspects of dental implants are evidenced by countless clinical reports in the dental literature. The treatments described may replace a single tooth, restore an edentulous arch, or rehabilitate an entire dentition. Individuals who are unable to wear conventional complete dentures today may be considered for one of several implant-supported complete-arch prostheses. In the case of a severely resorbed or atrophic maxilla, the introduction of zygomatic and pterygoid implants has heralded another major advancement over conventional complete denture prosthodontics thanks to more complex implant applications.

Irrespective of the scope of treatment, it is important that the implant-related procedures be guided by recognized surgical and prosthetic protocols and accepted clinical practices. Such groundwork will maximize the positive outcomes and minimize—if not prevent—complications with single implants, seven of which are identified and discussed in detail in this book.

The foundation for success relies on an understanding of implant biomechanics. The integration of dental implants (single root-form implants, zygomatic implants, wide-diameter implants, short implants, etc) and their varied applications are linked to more than two dozen implant biomechanical principles. In fact, there are those who contend that "the principles of biomechanics represent the interactions between the body (tissues) and the forces acting upon it (directly or via different medical devices)."[1] When understood and followed, these concepts contribute to the high success rates now associated with implant-supported prosthetic restorations.[1]

With that philosophical framework in mind, a central theme of this book is an emphasis on the adherence to implant biomechanics by clinicians who engage in any aspect of dental implant treatment. Furthermore, readers will note that five key aims are also developed as a central focus of the book:

1. To raise greater awareness of six complications associated with providing patients with a single implant and crown along with a lesser-known seventh complication presented by the authors.
2. To share the incidence levels/ranges associated with each of these seven potential complications.
3. To provide an explanation of the biomechanics related to single implants and their crowns. Clinicians who plan and treat patients with these concepts at the forefront of their thinking can minimize, if not prevent, clinical complications from arising during or after the various stages of treatment.
4. To offer a means to manage the different complications once they have been identified. The resulting strategy is based on a simple four-step process.
5. To equip clinicians to prevent future complications through an increased awareness of the key elements of implant biomechanics that may have been overlooked or not given the consideration they merited during the various stages of treatment.

By the end of this book, readers should have a greater understanding of the important role implant biomechanics play in achieving and maintaining successful single-implant treatment. It is hoped that clinicians

will know how to address these three questions: What went wrong? Why did things go wrong? How could the complications have been prevented? Answering these three questions will not only help to understand why a given complication may have arisen but also shine a light on an appropriate implant treatment going forward.

Reference

1. Manea A, Bran S, Dinu C, et al. Principles of biomechanics in oral implantology. Med Pharm Rep 2019;92(3):S14–S19.

Acknowledgments

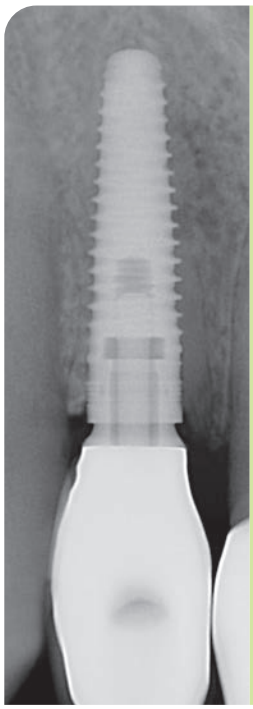
The authors extend their sincere thanks to Dr George A. Zarb for enriching this text with his enlightened perspective and thoughts conveyed across the pages of this book. To the generations of dentists who entered the dental profession after Dr Zarb's retirement, you missed the keen insight of his oral presentations, his masterful skills with the Queen's English, and the subtle humor his colleagues and friends enjoyed over the years. This is to say nothing of the enormous contributions he has made to prosthodontics at large and implant dentistry in particular. We cannot overstate the appreciation owed to Dr Zarb for his years of dedicated service to clinical dentistry, dental education, and research as well as for the professionalism he has extended to patients, dental students, dental residents, and practicing dentists from around the world. Thank you, Dr Zarb.

We also wish to acknowledge the dedication and hard work put forth by Quintessence Publishing Company, with particular thanks to William Hartman, former Executive Vice President and Director (now retired); Leah Huffman, Director of Editorial; Angelina Schmelter, Director of Production; and Sue Zubek, Graphic Designer.

1

Seven Common Complications with Single Implants

Since first introduced some six decades ago, dental implants have forever altered the dental profession for the better. While survival rates are high, single-implant treatment is not yet synonymous with problem-free clinical outcomes. Citing published research, this chapter provides readers with a balanced overview of prevalence and incidence data, survival rates, and the seven complications associated with single implants.



Chapter Highlights:

- Single implants are widely used on a routine basis to replace lost or missing anterior and posterior teeth by general dentists and specialists alike.
- Based on previous reports and more contemporary literature, the seven most common complications are, in rank order, *(1)* infraposition/infraocclusion, *(2)* interproximal contact loss, *(3)* abutment screw loosening and fracture, *(4)* fracture of the implant itself, *(5)* ceramic chipping and fracture, *(6)* loss of crown retention, and *(7)* remake of the implant-supported crown.
- Clinical success of single implants can be achieved by following biomechanical principles related to treatment planning, surgical placement, restoration, and patient management.
- A four-step process is proposed to minimize and/or prevent each complication: *(1)* diagnosis, *(2)* cause and effect, *(3)* management, and *(4)* prevention.

The successful integration of implants in bone, a process known as *osseointegration*, was first reported by the Swedish physician Dr Per-Ingvar Brånemark in his now-famous study involving rabbit tibia.[1] In 1965, Dr Brånemark placed his first oral implant.[1] Root-form dental implants were subsequently developed and later introduced to North America by Canadian prosthodontist Dr George A. Zarb and colleagues in the early 1980s. The history of this process of development, introduction, and acceptance in the dental community has been described in many publications and can be found elsewhere.[1-3]

Fast-forward to today, where oral care involving dental implants is offered routinely around the world and provided in a wide range of dental settings from operating rooms to conventional dental operatories/surgeries. Single-implant therapy is particularly well established and offered by a diverse group of practitioners to replace a lost or missing tooth in the anterior (Figs 1-1 and 1-2) or posterior (Figs 1-3 and 1-4) regions of the mouth.[4]

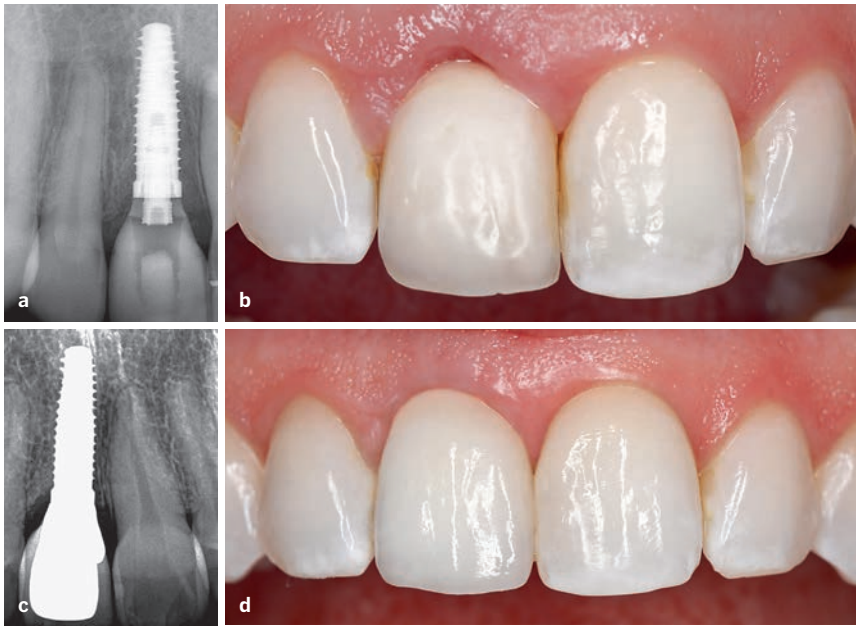


Fig 1-1 This patient suffered a traumatic injury that resulted in such substantial damage to the maxillary right central incisor that it could not be retained. *(a and b)* An implant was placed immediately upon extraction of the tooth, and a provisional crown was delivered at the time of implant placement. The radiograph shows the temporary abutment in the implant and the provisional crown. The clinical photo shows the mucosa at the time of provisional crown delivery. *(c and d)* Definitive crown in place. The clinical photo shows the healed mucosa around the implant.

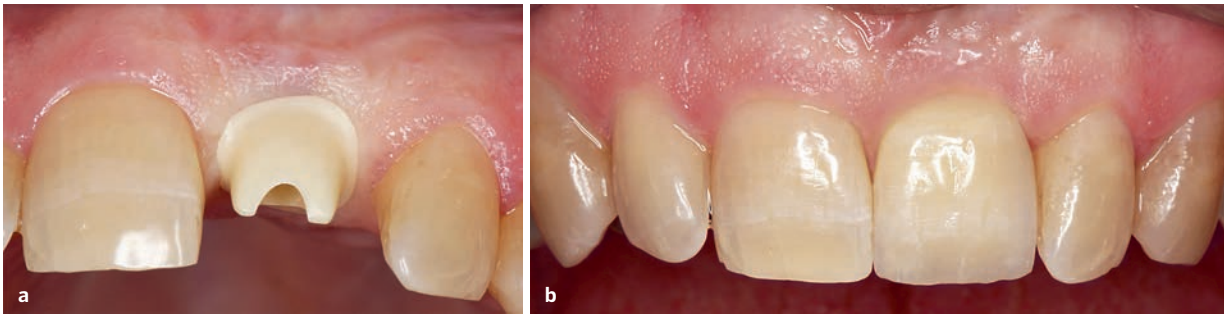


Fig 1-2 *(a)* A zirconia abutment was cemented over a titanium-base (Ti-base) abutment using Multilink Hybrid Abutment high-opacity (HO 0) cement (Ivoclar) and then attached to the implant using an abutment screw torqued to 35 Ncm. *(b)* The definitive crown was made using a CAD/CAM-milled zirconia coping that was veneered with a ceramic material (Cerabien ZR, Kuraray) and then cemented over the zirconia abutment using RelyX Unicem 2 resin cement (3M).

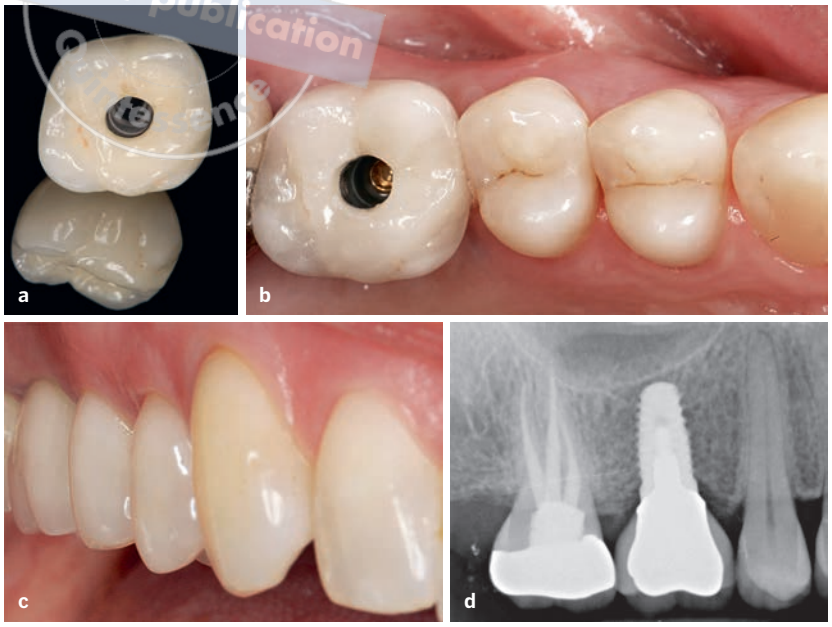


Fig 1-3 *(a)* A metal-ceramic crown was fabricated for the maxillary first molar implant. *(b)* The crown was attached to the implant through the occlusal screw access channel. *(c)* Frontal view of the completed crown. *(d)* Periapical radiograph of the implant and crown.

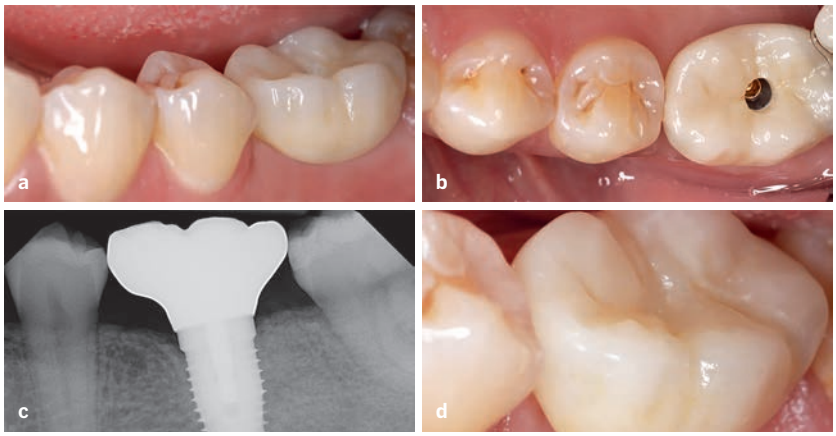


Fig 1-4 *(a and b)* The mandibular first molar was replaced with an implant and crown. *(c)* Periapical radiograph of the implant and crown. *(d)* Clinical photo after the occlusal access channel to the abutment screw was restored with composite resin.

The Explosion in Single-Implant Use

It wasn't long ago that a three-unit fixed partial denture (FPD) would have been proposed for the replacement of a single missing anterior or posterior tooth. Today, however, clinicians routinely recommend a single implant and crown rather than an FPD, describing dental implant therapy as a well-accepted and time-proven treatment option. If called upon, clinicians can readily support this recommendation with decades of research from evidence-based articles published in peer-reviewed scientific journals and numerous dental textbooks. Their proposed implant treatment is further supported thanks to a growing awareness among the general population that dental implants are a stable and long-term solution for tooth loss.

Needless to say, implant dentistry is an exploding field within dentistry. In fact, according to a 2018 article published in the *Journal of Dental Research*, in the United States alone, the prevalence of dental implant

Table 1-1 The prevalence of dental implants in the United States (past and future projections), plus the projected value for the global market by 2030

Time period	Prevalence[5]	Projected global market value (USD)[6-8]
1999–2000	0.7%	–
2015–2016	5.7%	–
By 2026	Up to 23% (projected)	–
By 2029	–	$6.52 to $8.60 billion[7] (projected)
By 2030	–	$9.62 billion[8] (projected)

use is projected to jump to 23% by 2026 from prior levels of 5.7% in 2016 and a mere 0.7% in 1999[5] (Table 1-1). What may be of even greater significance is there are no indications to suggest that this rapid growth trend will abate any time soon.

This expansion is further evidenced by the increased emphasis on training in implant surgery and related restorative procedures in dental educational programs in the United States and around the world. This is in addition to the demand for quality implant dentistry continuing education courses with classroom, laboratory, and clinical hands-on training.

In pure financial terms, projections put the "global dental implants market size" at ranging from $6.52 billion (USD) to as high as $8.60 billion by 2029[6,7] and up to $9.62 billion (USD) by 2030[8] (see Table 1-1). North America accounts for the largest share of this dental implant market as of 2023, followed by Europe.[6]

At the same time, implant manufacturers continue to offer the dental profession new products, improved diagnostic tools,[1] and innovative technology coupled with privately and government-supported clinical research. In single-implant surgery, for example, the dental profession has witnessed an evolution from freehand implant surgical placement to enhancements using sophisticated surgical guides. Moreover, clinicians today now have the option to perform robotic implant surgery, not to mention the ability to replace articulating media with computer monitoring of chewing patterns.[1]

Whether due to new and ever-improving technology, advances in clinical procedures, or expanded clinical applications, implant survival rates as high as 98.6% are not uncommon[9-14] (see Table 1-4). As a consequence, more clinicians are recommending single-implant therapy as the treatment of choice for the replacement of an individual tooth (see Figs 1-1 to 1-4). The growing public awareness of successful clinical outcomes has also spurred dental patients to seek implant treatment entirely on their own. Such behavior is in stark contrast to a few decades ago when dentists were still espousing the benefits of an FPD over a removable prosthesis during their patient treatment planning appointment.

Remaining Challenges with Single Implants

While technical advances positively enhance the dental implant landscape, clinicians continue to encounter clinical challenges. In related articles published in 2003[15] and 2018[16] by one of the authors (CJG), six potential prosthetic complications were identified that affect single implants and their crowns (Table 1-2): abutment screw loosening, implant fracture, fracture or chipping of the ceramic veneer, loss of crown retention, open proximal contacts, and remake of the implant-supported crown.

Several years later, those same issues continue to surround single-implant treatment,[17–36] along with a seventh adverse clinical outcome not reported in two previous studies[15,16]: altered implant position (infraposition/infraocclusion) attributed to continued facial growth (especially in young patients). See Table 1-3 and Figs 1-5 to 1-14. Bear in mind that this latest finding is not actually "new" in the sense that it was only recently discovered. It is more accurate to report that it was previously identified but the condition was not as widely known or publicized as the other six complications. Depending on the complexity of the specific changes that take place, infraposition/infraocclusion can be quite difficult to manage. This newly added seventh complication can present a unique set of challenges and limitations for patients and clinicians alike (see chapter 3).

Table 1-2 Prosthetic complications previously reported with implant prostheses[15,16]

Type of prosthesis	Number of complications
Implant overdentures	17
Implant fixed complete dentures	9
Implant single crowns	**6**
Implant FPDs	4

Table 1-3 Seven complications linked to single implants and their crowns in order of incidence rates

Complication	Incidence range[a]	Relevant chapter in this book
1. Infraposition/infraocclusion (Fig 1-5)	17.6%[17] – 100%[18–21]	3
2. Interproximal contact loss[b] (Fig 1-6)	17%[22,23] – 66%[24–26]	4
3. Abutment screw loosening (Fig 1-7)/fracture (Fig 1-8)	1.0%[27] – 14.7%[28]/0.06%[29] – 1.2%[30]	5
4. Single-implant fracture (Fig 1-9)	0.20%[31] – 0.92%[32]/12.7%[33c]	6
5. Ceramic chipping (Fig 1-10)/fracture (Fig 1-11)	0.0%[34] – 11.8%[35]/0.0%[28] – 2.9%[28]	7
6. Loss of crown retention (Fig 1-12)		
Titanium implants (definitive cement)	0.0% – 4.3%[28]	8
Zirconia implants (definitive cement)	0.0% – 2.9%[37]	8
7. Remake of the implant-supported crown (Figs 1-13 and Fig 1-14)	0.0%[35] – 1.9%[36]	9

[a]Due to wide variations in the outcomes data, incidence ranges are reported rather than a mean rate.

[b]Technically, Kandathilparambil et al[23] reported a 15% incidence rate but with 40 mandibular first molars and the patients wore an Essix retainer. The 17% incidence rate for the low end of this range appears in this table because the French et al[22] study involved a much larger sample size of 4,325 implants. This is likely more representative of the low end of the range.

[c]Chitumalla et al[33] reported a 12.7% incidence rate with a much smaller test population (n = 157) than Lee et al,[32] and their subjects included bruxers.

Fig 1-5 The maxillary right lateral incisor implant was placed before facial growth was completed, and the crown is now infrapositioned and out of occlusion with the opposing teeth after 9 years in function. This is an example of complication #1 (infraposition/infraocclusion).

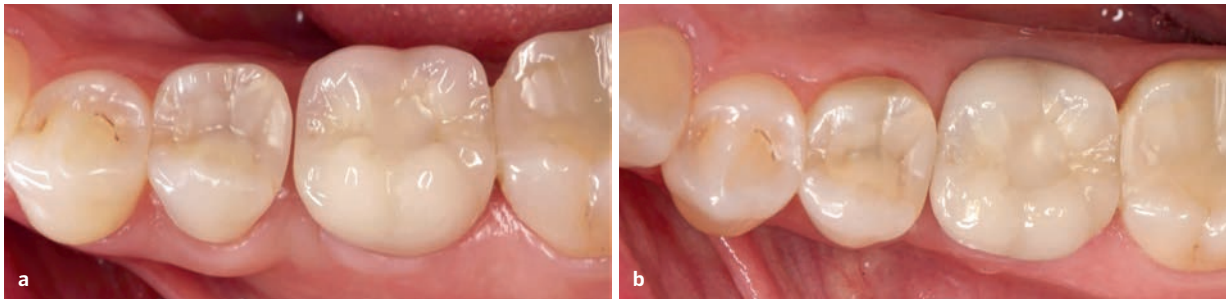


Fig 1-6 *(a)* Six years after placement of the crown on the first molar implant, the mesial interproximal contact opened and food was collecting in the space. *(b)* The composite resin restoration on the distal surface of the second premolar was replaced to reestablish the proximal contact. This is an example of complication #2 (interproximal contact loss).

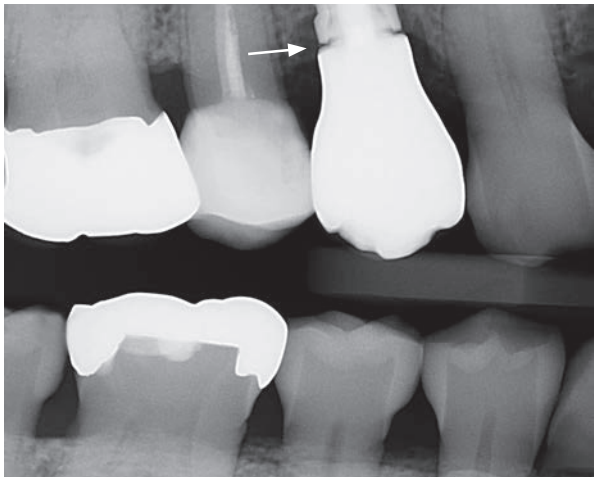


Fig 1-7 The bitewing radiograph shows a maxillary first premolar implant crown where the abutment screw became loose. Space *(arrow)* is now visible between the crown and the implant on the radiograph. This is an example of complication #3 (abutment screw loosening).

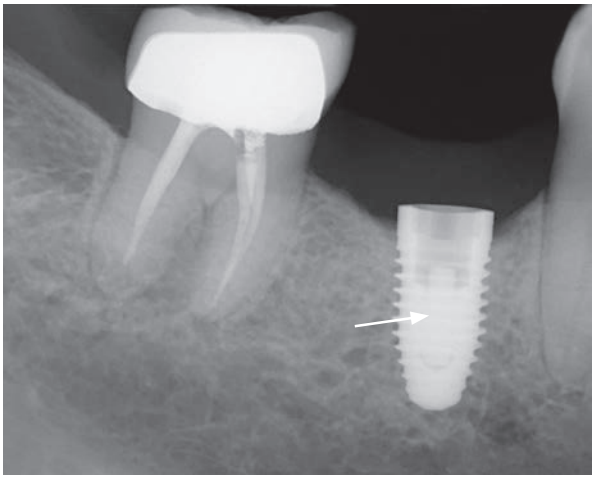


Fig 1-8 The *arrow* points to the apical portion of a fractured abutment screw still lodged inside the implant. Note that the implant is positioned toward the mesial aspect of the edentulous space rather than being centered. Because of this positioning, the crown had an extension distal to the implant that placed adverse leverage on the crown, which then led to abutment screw fracture. This is an example of complication #3 (abutment screw fracture).

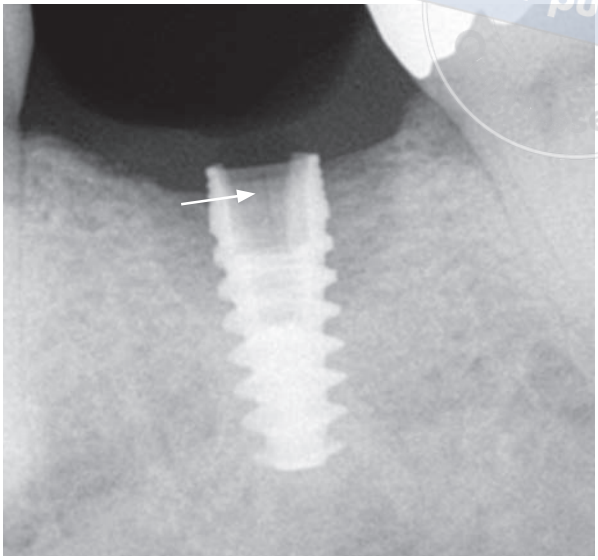
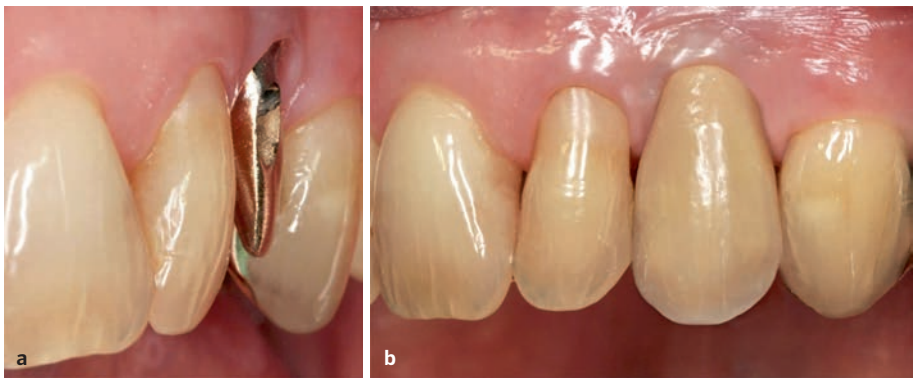


Fig 1-9 The combination of a bruxing habit with a distally positioned implant and a nonworking-side occlusal interference caused this implant to fracture *(arrow)*. This is an example of complication #4 (single implant fracture).

Fig 1-10 The superior portion of the ceramic veneer on this zirconia all-ceramic restoration is chipped. The cause of the chipping was assumed to be occlusal forces, although an occlusal interference may have been responsible for the chipping. This is an example of complication #5 (ceramic chipping).

Fig 1-11 A portion of the facial aspect of this monolithic zirconia crown on the maxillary second molar implant has fractured from the underlying abutment. The crown must be replaced. This is an example of complication #5 (ceramic fracture) and complication #7 (remake of the implant-supported crown).

Fig 1-12 *(a)* The crown on the maxillary left canine implant came loose due to the use of a provisional cement and an abutment with a smooth surface and substantial faciolingual convergence. Both of these factors resulted in less than ideal retention. *(b)* Facial view of the definitive crown after recementation with a resin luting agent. This is an example of complication #7 (remake of the implant-supported crown).



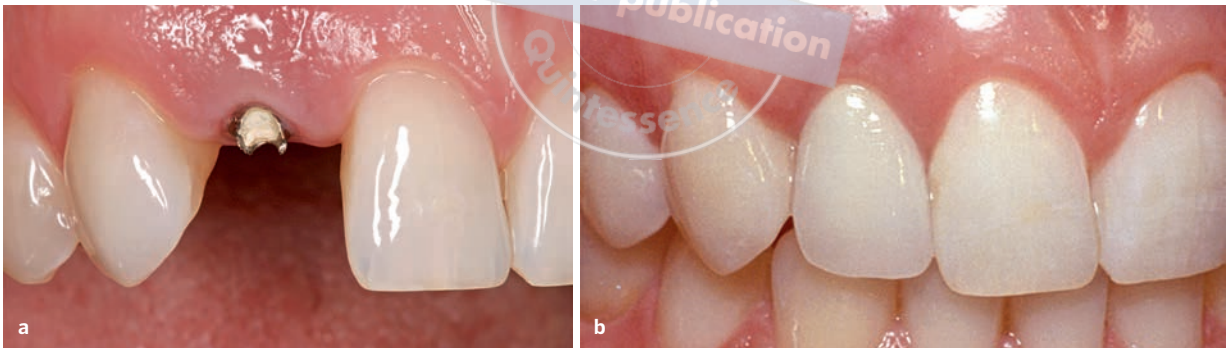


Fig 1-13 *(a)* The abutment attached to the maxillary right lateral incisor implant fractured, necessitating a remake of the abutment and crown. *(b)* After whitening the teeth, a new abutment and crown were placed. This case is also an example of complication #7 (remake of the implant-supported crown).

Fig 1-14 *(a)* Both maxillary central incisors were extracted with implants placed immediately, resulting in substantial mucosal recession. The patient was not satisfied with the esthetic result. The central incisor implant-supported crowns were overcontoured cervically. Gingival recession followed the extraction of the adjacent natural teeth and implant placement. *(b)* To help improve the esthetic outcome, the two single-implant crowns were remade by one of the authors (CJG) but with flat submucosal contours that included the addition of cervical pink porcelain. The reduced cervical crown contours permitted the mucosa to migrate incisally, but it required an entire year for this positive tissue change to occur. While the use of pink porcelain did not produce an ideal esthetic result, it did improve the two implant-supported central incisor crowns to the point where the patient was satisfied with the final result. This is another example of complication #7 (remake of the implant-supported crowns).

Single-Implant Survival Rates and Potential Complications

While FPDs remain an option for patients with financial constraints, limited access to implant care, personal preferences against surgical treatment, or health issues, a well-planned single implant and crown can be a more successful and advantageous treatment modality. Clinicians can offer single implant treatment with confidence knowing their recommendation is backed by decades of evidence-based research.

Select examples of published research reports with positive short-term and long-term survival rates of single implants appear in Table 1-4.[9–14] The data drawn from these six articles range from a 4-year survival rate of 97% (for 459 patients) to an 18-year period with a 98.6% survival rate.[9,11] These studies represent data from nine nations collected over 19 years (2000 to 2018) and provide a global perspective. However, it is important to note that *(1)* survival rates may vary based on the experience level of the clinician and *(2)* complications still occur despite excellent survival rates.[12]

To put this in a contemporary context, although a single implant may remain osseointegrated for many years, that does not mean complications won't arise during that time. It is this duality (survival vs complications) that clinicians should bear in mind when planning and proposing single-implant treatment to their patients. In a 2021 article, Kaur et al[38] pointed out that while published reports often include implant survival data, readers do

Table 1-4 Select reports with single-implant survival rates

Authors	Year	Survival period	Survival rate (%)	No. of implants (n)
Creugers et al[9]	2000	4 years	97.0%	459
Krennmair et al[10]	2010	5 years	98.3%*	541
Andersson et al[11]	2013	18 years	96.8%	65
Pjetursson et al[12]	2012	5 years	94.5%	465
Pjetursson et al[12]	2012	10 years	89.4%	69
Mozzati et al[13]	2015	10 years	90.5%	181
Beschnidt et al[14]	2018	5 years	98.6%	271

*Involved "root-shaped screw-type dental implants."[10]

not always come away with a "full picture of the rate of complications." To appreciate this particular perspective, it is helpful to separate the two concepts—survival and complications—and analyze them individually.

Survival

Take a moment to reflect on the meaning of the word *survival* as it is applied to single dental implants. Think of this term as indicating the percentage of root-form dental implants that remain functional over a specified length of time. In other words, how many implants "survived" to the end of a study? None of the studies included in Table 1-4 reported 100% survival. For a variety of reasons, a certain number of implants were lost (failed) during each study period. In a 2019 article, Manea et al[39] summed it up rather succinctly when they wrote that "no therapy is without failure risk."

Even when implant survival rates approach 99% (see Table 1-4), there will be a real number of clinical failures—1%. That may be a very small percentage, but think in terms of the sheer volume of single implants placed every year around the world. Even 1% of that number would translate to a sizeable number of affected patients.

According to some non-peer-reviewed publications, dental patients receive between 3 and 5.5 million dental implants in the United States annually.[40] For the sake of illustration, let's assume a figure of 3 million implants placed annually represents a reasonable estimate just for the United States and apply a survival rate of 99%. In the best of scenarios, 30,000 would be the estimated number of nonsurviving implants each year. That is no small number of implants in need of replacement. Should the number of implants placed be closer to 5.5 million per year, the estimated number of annual failures then jumps to 55,000. If the actual survival rate is below 99%, the estimate of failed single implants becomes even higher, and this is just for the United States. Furthermore, these calculations pale in comparison to the estimate of "up to half a million" implant failures in 2021 reported by Kaur et al,[38] who considered longitudinal survival rates of osseointegrated dental implants to range from 90% to 95%.

Nonetheless, based on the long-term data in Table 1-4,[9–14] the reported survival rates for simple-implant treatment range from 89.4% to 98.6%. When discussing potential treatment with patients, the underlying concept to emphasize is that implant survival data are high, but there should be no implication of 100% survival for 5 years, 10 years, or longer for single implants and their crowns.

Now we've covered the survival side of single-implant treatment. Next let's review the complications linked to single implants and the reported incidence ranges for those complications.

Complications

Problems can and do arise with implants and their crowns. Look at Table 1-3 again. Irrespective of how long an implant has been functioning in place, these seven complications may arise. Once diagnosed, they will have to be addressed during the period of their survival (or what we may refer to as their *service life*). Even with a very low incidence rate, an adverse outcome of any sort can pose significant difficulties for the patient and challenges for the clinician trying to resolve it.

That being said, fracture of the single implant is the only complication that truly impacts implant survival. Of course, abutment screw fracture could lead to the need to replace an implant should retrieval of the screw fragment(s) not be possible, but the remaining complications generally pertain to the status of the implant-supported crown and can usually be managed without having to remove and replace the implant itself. In other words, implant survival is not necessarily negatively impacted by all seven complications in the same way.

Again, it is helpful to think of implant survival and implant complications as separate but related concepts. As Manea et al[39] once pointed out, "A good understanding of the biomechanics involved in oral implantology can lead to higher success rates in implant-supported prosthetic restorations." That increased success can in turn be accompanied by fewer technical complications when there is greater compliance with implant biomechanics, as discussed in this book.

Types of Implant Complications

In the 2021 article by Kaur et al[38] referred to earlier, the authors wrote about two types of implant complications: biologic and prosthetic. In an often-cited 2012 systematic review, Jung et al[41] compared and assessed three types of single-implant complications: *(1)* biologic, *(2)* technical, and *(3)* esthetic. Other popular labels for complications mentioned in the literature include surgical, mechanical, phonetic, etc. Under each of these broad groupings, authors may then itemize various clinical experiences in different "categories."

Continuing with examples of biologic complications mentioned by Kaur et al,[38] the authors described two categories of potential outcomes: peri-implant mucositis and peri-implantitis. On the other hand, Jung et al[41] identified seven different categories of complications under the biologic umbrella: soft tissue complications, signs of inflammation, mucosal inflammation, mucositis, bleeding, suppuration, and soft tissue dehiscence. Jung et al[41] also mentioned five technical categories of complications and listed them in rank order of occurrence as abutment-loosening, screw loosening, loss of retention, fracture of the crown ceramic veneer, and implant fracture. Under the umbrella of esthetic complications, Jung et al[41] included three items: soft tissue dehiscence exposing the crown margin, suboptimal color of the restoration, and general esthetic issues (papilla height for example). These authors also pointed out the lack of standardization of criteria used to assess and evaluate esthetic complications. Goodacre et al[15,16] chose to divide complications into eight types: surgical, implant loss, bone loss, peri-implant soft tissue, mechanical, esthetic, phonetic, and prosthetic.

Note that these categories are still sufficiently broad to allow room for even more detailed information. Take Jung et al's category of "signs of inflammation,"[41] for example. Are those signs localized or generalized, acute or chronic, minor or severe, treatable nonsurgically or surgically, and so on? Given this complexity, it is recommended to look for specifics when reading reports that describe patient situations that fall into one or more of these types and categories of complications linked to single implants.

Incidence and Timing of Complications

Incidence

Aside from knowing which adverse changes may occur over time, another variable clinicians should be aware of is the incidence (frequency) with which the different postoperative complications reportedly may arise (see Table 1-3). One could reasonably deduce that the incidence data are more accurate when a complication is tracked and reported in a larger number of studies. With a limited number of reports, it is not possible to know whether that specific adverse outcome is a rare occurrence or not, until such a finding is more widely reported or identified in larger patient populations.

Timing

Kaur et al[38] described implant complications by combining categories with time. More specifically, the authors mentioned clinical scenarios in which the biologic and prosthetic complications included adverse outcomes that were "early" and "late" in the course of treatment. The use of descriptive labels (type and category) coupled with time references (early vs late), even if slightly different from one another, can be helpful when clinicians read and assess comparable clinical findings in other publications. This information should also prove valuable for practitioners who eventually plan to or are currently providing implant treatment.

Multiple Concurrent Complications

An added consideration is that several implant complications can occur simultaneous to one another. In other words, clinicians should not focus solely on the incidence rates of opening proximal contacts, abutment screw loosening, or loss of crown retention but also think of these potential complications in the aggregate as overall frequency. In the event that any complication is encountered, indications of the remaining six should be looked for and evaluated.

In a 2012 article, Camargos et al[42] combined the complication data of three types (inflammatory, prosthetic, and operative) to arrive at an overall complications rate of 29.6%. On the other hand, Kaur et al[38] reported a 10.8% overall incidence of technical/mechanical complications for single implants. Recall that the categories of complications they referred to actually included implant screw loosening, implant screw fracture, prosthesis fracture, debonding of the prosthesis, and/or implant fracture.[38] Citing previously published reports, they also described the incidence rates of peri-implant mucositis as occurring in up to 65% of patients, concluding that the incidence rate of peri-implantitis could range from 10% to as high as 47%.[38]

Managing Clinical Complications from Diagnosis to Prevention

If you place and/or restore enough single implants, you can expect to encounter one or more of the seven implant-related complications listed in Table 1-3. When considering how to manage each implant complication, the authors recommend following a four-step process (Box 1-1): *(1)* diagnosis, *(2)* cause and effect, *(3)* management, and *(4)* prevention.

How should you begin?

Any complication management begins with a comprehensive oral examination to locate and identify each problem to be evaluated. Never be surprised if you find more than one complication or a potential complication that is developing. This oral examination will help you achieve a diagnosis as to what happened (step 1), and the cause and effect (step 2) can then be determined. Based on the information collected and the current status of the patient, realistic options can be weighed to manage the complication (step 3). It is essential that you understand what occurred before proposing and initiating treatment in order to manage the complication effectively and prevent future problems (step 4). You don't want this complication to arise again with this same patient or in other patients whom you may treat similarly in the future (see Box 1-2).

1. Diagnosis

When the patient presents with a problem or simply for a follow-up appointment, it is prudent to update the patient's medical history, obtain blood pressure readings, and perform a comprehensive oral examination. As part of this assessment, determine if there are obvious

Box 1-1 Four steps to managing complications with single implants

1. Diagnosis
2. Cause and effect
3. Management
4. Prevention

indications that any principles of implant biomechanics have been compromised. Those principles, 25 in all, are presented and discussed in detail in chapter 2. Keep in mind that multiple small problems can compound and even worsen over time, particularly if not addressed early. Always classify complications by type and category and, when possible, designate them as early or late changes. Being organized in your documentation will help you avoid bigger problems down the line.

2. Cause and effect

A cause-and-effect perspective is helpful when evaluating each negative outcome (the effect) and the biomechanical principle(s) that may have been overlooked or not followed (the cause). With some patient situations, treatment may have violated multiple biomechanical principles and thus warrant management in more than one way.

It is important to understand that adverse outcomes do not need to be commonplace, provided treatment complies with and does not violate any of the recognized principles of implant biomechanics. In other words, it is not unreasonable to assume that complications can be avoided, and those complications that do arise can be managed with varying degrees of success. Make a concerted effort to identify and correct the root cause(s) that may involve knowingly or unknowingly violating certain biomechanical principles.

3. Management

Once a complication has been diagnosed, evaluate the extent of any adverse changes and come up with a list of options to achieve resolution, recognizing that there may be circumstances when simple corrective steps are no longer possible. The nature and/or extent of some problems can be so extensive that removal of the entire assembly (implant and crown) is advisable. But in many instances, simply retightening or replacing a screw, recementing a crown, or closing a proximal contact by adding or replacing an adjacent restoration or the implant-supported crown is sufficient. Keep in mind that based on the nature of the complication and the potential delay in addressing it, peri-implant mucosal inflammation, localized infection, mucosal recession, bone loss, and other periodontal conditions may develop and require adjunctive periodontal therapies before implant retreatment.

Think of the management of complications as a process unto itself with degrees of engagement from basic to challenging. Be mindful of the "overall complications" rate as an acknowledgment that more than one problem may have to be addressed and resolved. In a similar vein, expect to encounter patient situations where significant time, effort, and expense would need to be expended to "save" an existing crown or implant. Under those circumstances, it might be more prudent and practical to declare the situation a failure and proceed directly to retreatment. Of course, such clarity is invariably seen in hindsight and often only with the benefit of years of experience managing numerous unfavorable patient treatment outcomes.

4. Prevention

Once a clinical complication has been identified, diagnosed, and managed with some sort of "fix" (remedy) or a recommendation to retreat, a postoperative assessment should be undertaken to focus on questions specific to the complications involved (Box 1-2). Such a strategy helps to minimize—if not prevent—recurrences,

Box 1-2 Three key questions to answer when assessing implant complications

1. What went wrong?
2. Why did things go wrong?
3. How could this situation have been prevented?

assuming the original treatment was not aligned with one or more key biomechanical principles associated with single-tooth implants.

Make a concerted effort to learn from each patient situation to avoid future missteps in the planning and execution stages that might otherwise lead to a repetition of those same complications. After all, the overall goal is to provide implant treatment with a long service life unencumbered by clinical complications.

Conclusion

Diagnosing and correcting implant complications can be challenging for clinicians, not to mention inconvenient and costly for affected patients. This is particularly true when clinicians are unaware of the potential for specific types of complications to occur. While 100% implant survival with every patient is an admirable goal, implant loss (failure) remains a potential risk, if only to a limited degree. It is unrealistic to expect a 0% complication rate over the life of an implant.

For the benefit of all concerned, understanding and applying the fundamental principles associated with single-implant biomechanics go a long way in minimizing complications, if not preventing them from arising in the first place (see chapter 2). Citing published research, this chapter provided an overview of those complications that continue to be linked to single implants and their crowns. Armed with data collected from your own implant patients, you may improve treatment outcomes once you learn how to diagnose complications shortly after they arise, manage each issue properly, and take appropriate steps to prevent those unplanned outcomes from recurring.

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