Abstract
The gap existing around immediate implants seems to beg for management guidelines. Guidelines that provide consistent, predictable results but do not require the clinician to be intimately familiar with the entirety of the vast body of literature on the topic. This summary review intends to inform the clinician about the historical basis for the concern of the immediate peri-implant gap and how it ought to be managed in clinical practice.

Objectives
After reading this article, the reader should be able to:
• Recognize the immediate peri-implant gap and appreciate the historical basis for concern related to its presence.
• Understand some of the methods of gap management available.
• Evaluate the implications of apparent support from the literature for various modes of gap management.
• Recognize the potential importance of appropriate gap management as it relates to immediate implant placement.
• Engage other articles on gap management from a position of comprehension for the broader scope of experimental and clinical implant dentistry.

Introduction
A conventional implant protocol generally calls for the preparation of an osteotomy a few tenths of a millimeter narrower in diameter than the planned implant fixture, so as to provide a tight fit for the purpose of achieving sufficient primary stability. Primary stability—the rigid
fixation of a dental implant relative to the surrounding bone during the healing phase of the implant—is seen as a virtually necessary prerequisite for successful osseointegration.

With the advent of immediate implant dentistry, implant fixtures are now regularly placed into fresh extraction sockets that, at their most coronal aspects, are sometimes much larger than the diameter of the implants being placed. Primary stability is generally achieved at the apical aspect of the implant fixture, but there is usually somewhat of a gap between the circumferential aspect of the immediate implant and the extraction socket wall. The dimensions of this gap—sometimes referred to as the jumping distance—will vary depending on a number of factors, such as tooth type, the particular morphology of the extraction socket and the diameter of the implant being placed.¹

Needless to say, management of this immediate peri-implant gap has become a novel challenge. This is particularly true of the buccal or labial gap because the appropriately heightened focus on both function and aesthetics in contemporary implant dentistry dictates that the facial profile of the implant restoration be developed in harmony with the surrounding tissues. The presence of a peri-implant gap affects both hard and soft tissue healing, and if not properly managed, may compromise function and jeopardize aesthetics. With our current knowledge, what are the best recommendations for gap management in order to achieve the most consistent and predictable functional and aesthetic results?

The objective of this review will be to examine the literature pertinent to the gap surrounding the immediate implant and to develop therapeutic guidelines for gap management in clinical practice. For the purposes of this review, a sampling of data is presented to establish an historical continuum on the immediate peri-implant gap, followed by an evaluation meant to form the basis for a set of well-defined therapeutic guidelines for managing the gap in a consistent, predictable and efficacious manner.

**Literature Review**

In 1999, an early investigation by Dr. Ken Akimoto studied the effect of gaps of varying dimensions surrounding implants in dogs.² For the purpose of this study, simulated extraction sockets were created by over-preparing the coronal extent of the osteotomy sites to a larger diameter than appropriate for the implants placed, while the apical extent was appropriately sized to provide adequate primary stability (Figure 1). Using this method, test osteotomy sites were prepared with 0.5mm, 1.0mm and 1.4mm circumferential gaps surrounding the fixtures in order to simulate the immediate peri-implant gaps between fixtures and the socket wall during immediate implant placement, while control sites were prepared that appropriately fit the implant fixtures similar to a conventional drilling protocol.

When the study was completed at 12 weeks, all fixtures in both control and test groups were firmly held in bone and exhibited complete clinical bone fill, regardless of initial gap measurement. However, upon histologic evaluation, it was noted that a fibrous connective tissue seam had advanced apically to varying depths in the test sites. This had a deleterious effect on the most coronal bone-to-implant contact, and the wider the initial gap, the more apical the fibrous seam had advanced. This investigation employed machined surface implants, and because it is now known that roughened implants have consistently been shown to cause a stronger bone response³ and demonstrate a positive effect on bone-to-implant contact⁴ for conventionally placed fixtures, the application of this data to clinical practice may be limited.

In 2001, Dr. Michele Paolantonio published a split-mouth study looking at 48 patients, each of whom received both a conventionally placed implant in a previously healed site (control) as well as an

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Immediately placed implant in a fresh extraction socket (test) where the gaps were less than or equal to 2mm wide. Clinical and histological evaluations performed one year following implant placement demonstrated that the clinical outcome and degree of osseointegration for implants placed into fresh extraction sockets with a minimal gap (less than or equal to 2mm) and no use of barrier membranes did not differ from that of implants placed into mature, healed bone.

In 2005, Dr. Daniele Botticelli published an investigation on gap resolution in a dog model that included histological analysis. Comparing both machined surfaces versus roughened surfaces as well as a submerged protocol (cover screws placed at the time of implant placement) versus a non-submerged protocol (healing abutment placed at the time of implant placement), all sites received no graft material to fill the standardized 1.25mm gap at the most coronal aspect, although resorbable barrier membranes were utilized (specifically perforated in the center to permit coverage of the gap around exposed healing abutments for the non-submerged protocol). Histology at four months revealed gaps filled with regenerated, integrated bone against the roughened surfaces, while fibrous seams were consistently detected between the machined surfaces and the bone fill of those defects. Additionally, the microscopic bone-to-implant contact was statistically significantly less for machined surfaces than for roughened surfaces.

All studies reviewed thus far have either looked at no gap management or management solely with a barrier membrane, but utilizing no bone graft material placed into the immediate peri-implant gap. The next two examples will take a look at investigations incorporating the use of particulate bone graft material placed into the gaps along with the use of barrier membranes.

In 2003, Dr. Thomas Wilson showed results of a human case study of very limited power, but which is included in this review because the gaps encountered were of a relatively excessive dimension compared to

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Fig. 2: The three dimensions of the immediate peri-implant space. The left side of the diagram depicts an axial perspective, where we can observe both the horizontal defect width and the vertical defect depth. The right side depicts an occlusal perspective, where we can observe both horizontal defect dimensions – both the previously recognized bucco-palatal/lingual dimension, as well as the newly appreciated mesio-distal dimension.
what has been reviewed so far. Of the 14 immediate peri-implant gaps, eight gaps measured from 0 to 1.5mm, two gaps measured 1.5 to 4.0mm and four gaps measured greater than 4.0mm. All gaps were treated with methods previously used for guided bone regeneration (GBR) against teeth, such as the use of particulate bone graft material, enamel matrix derivative and resorbable collagen membranes, all secured under primary closure of the gingival flaps. Upon histologic examination, bone-to-implant contact for the widest gaps (greater than 4.0 mm) was similar to that of the narrowest gaps (0 to 1.5mm), thus confirming that gap management can be successful in promoting osseointegration in even very wide gaps (greater than 4.0mm).

In 2004, Botticelli provided histologic evidence that gap management with particulate bone particles and a resorbable collagen membrane can result in osseointegration within the area of the gap. Employing artificially created extraction sockets in a dog model that exhibited circumferential gaps of 1.25mm following implant placement, the investigators studied the effects of bovine bone particles placed into the socket (both with and without use of a resorbable membrane) versus no graft particles placed (again, with and without use of a resorbable membrane). Although histologic analysis revealed no statistically significant differences between any of the groups, such results were perhaps expected because of the small dimension of the gaps.

Even though these studies show that gaps may tend to heal spontaneously or that, when compared to doing nothing, gap management protocols seem to show similar results in terms of clinical bone fill, the body of literature does endorse grafting the gap to prevent more drastic hard tissue changes. In a 2009 systematic review, Dr. Stephen Chen showed that grafting the gap serves to prevent more drastic hard tissue changes. In a 2009 systematic review, Dr. Stephen Chen showed that grafting the gap serves to help reduce horizontal bone resorption, and dog studies by both Dr. Mauricio Araújo in 2011 and Dr. Marco Caneva et al. in 2012 demonstrated both more coronal histologic bone-to-implant contact and thicker facial bone following grafting. Data from these and other studies therefore provide a compelling endorsement to engage in gap management for the sake of maintaining the horizontal dimension of the alveolar ridge, promoting both superior ridge morphology as well as more favorable soft tissue architecture.

In 2011, Drs. Dennis Tarnow and Stephen Chu discovered that it is possible for an exceedingly large gap to fill with integrated bone verified with histology in a human without any management of the gap whatsoever. In a case presentation regarding an extracted maxillary canine, an immediate implant with a healing abutment was placed with a 4.2mm horizontal gap to the facial plate and was permitted to heal without any management techniques. The fixture was removed for histology 10 months following implant placement (and five months following occlusal loading) along with some facial bone. Osseointegration of the facial plate was confirmed via histology, serving to confirm that the gap had, in fact, filled in with more than just apparent clinical bone fill.

Discussion

Although one might suppose that reviewing the relevant publications is the more difficult task for one who wishes to be a scholar of the literature, it is really the appropriate assimilation of the collected information that serves to be the more challenging undertaking by far. Each group of investigators regularly develops and utilizes its own methodology and, often times, the techniques employed in one investigation do not match those of another investigation, and so the results of the two cannot be perfectly correlated.

For example, studies performed in a dog model generally employ artificially created peri-implant gaps that do not necessarily create conditions equivalent to an extraction socket. Gaps in fresh extraction sockets exhibit a greater tendency to show histological evidence of bony regeneration while surgically created troughs in the alveolar ridge do not. Furthermore, surgically created troughs exhibit gaps of uniform depth and width, while naturally occurring gaps surrounding actual immediate implants in humans do not. However, as a model that permits much more readily available histological data, implant studies in an animal model certainly possess some advantages over human studies.

A recent review of gap management concepts and techniques asserted that the immediate peri-implant gap consists of two dimensions: the horizontal defect width (between implant circumference and socket wall) and the vertical defect height (the distance between the most coronal aspect of the socket wall and the most coronal point of macroscopic contact between the fixture and the socket wall). But the peri-implant gap exists in three dimensions, and so must consist of three dimensions. In addition to the horizontal dimension of the gap between the implant and the socket wall and the vertical dimension of the gap between the most coronal aspect of the facial plate and the depth of the defect, there is also a third dimension of the gap, accounted for by authors such as Chen, in the horizontal direction perpendicular to the aforementioned horizontal direction. This dimension is parallel to the tangent to the circular platform of the implant (Fig. 2).

Because this (literally) adds an entirely new dimension to the data collection and analysis, many investigators either do not collect this information or do not include it in the presentation of their data for simplicity’s sake. The trouble is that without consistent reporting of this dimension, its effect on both spontaneous gap resolution and attempts at gap management are largely unknown.

Notwithstanding these well intentioned attempts at making the data more accessible to both the investigator and reader alike by avoiding what would otherwise be a thoroughly unwieldy experience of evaluating permutations of complex statistics for each of the three dimensions of the peri-implant space, such gap dimension simplifications generate the notion that the space between the immediate implant and the wall of the extraction socket is a two dimensional gap as it appears in a histologic photomicrograph or a cartoon drawing, instead of the three dimensional volume of subcrestal airspace that it truly is. It is therefore with ambivalence that the...
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I have limited the focus of this current review in a similar fashion to reduce the complexity of data analysis, and the portions of the studies presented above therefore relate only to the horizontal gap between fixture and socket wall, making direct comparisons between studies more manageable, albeit somewhat misleading. Overlooking these confounding variables permits data to be more readily understood and generalizable, but with less precision, serving to underscore the true difficulties inherent in proposing guidelines of best practice with leniency.

Another issue plaguing the endeavor of data comparison between investigations is that of differing surface technology among study implants. Many of the studies were done on the additive titanium-plasma sprayed (TPS) surface, which implant manufacturers have replaced with subtractive surface technology as the surface technology of choice, such as etched or blasted roughening techniques. The data from the TPS implant studies may not be generalizable to the more moderately or mildly roughened surfaces in use today, or the surfaces of tomorrow, which have yet to be defined. Furthermore, differences in implant design among brands and product lines lead to considerable differences in the three dimensional space of the peri-implant gap and may affect clot retention, which is what is ultimately responsible for successful turnover of the healing gap site into bone.

Another confounding variable is differences in surgical technique among clinicians. In the first five studies reviewed above, flaps were raised for surgical access to the alveolar bone during surgical placement of the implants and sutured for either primary closure or near primary closure with healing abutments allowed to remain exposed. In the last study, Tarnow and Chu specifically did not raise a flap for the extraction of the tooth in question, and so there was no flap to suture, let alone coronally advance over the gap.

The current consensus among a number of foremost investigators and clinicians is that flaps should not be raised from the facial bone if it can be avoided because doing so severs an important source of vascularization to the delicate facial plate, which might be as thin as less than 1mm in the maxillary anterior sextant. Because the aesthetics of the facial aspect of the alveolar ridge is of tremendous importance, the focus of gap management is often specifically on the gap between the implant and the facial plate. And because the facial plate of bone is responsible for maintaining the blood clot that will eventually turn over into new bone, if the facial plate is lost before the gap attains an as yet unspecified threshold of healing, a residual gap is likely to result.

When the facial plate is greater than or equal to 1.8mm thick, less resorption is expected and retention of the blood clot is more predictable over the length of time necessary for gap resolution. But as mentioned earlier, such a facial plate thickness is rare in the anterior sextants, and so it is often recommended to selectively employ a more aggressive gap management protocol in the anterior than in the posterior, where facial plates are often in excess of 1.8mm in thickness.

Conclusion

From this literature review, it should be clear that peri-implant gaps need not be specifically managed at all for a favorable outcome to necessarily occur. From the perspective of anatomy and physiology, it truly is amazing to read about a 4.2mm gap resolving itself with no clinical input following immediate implant placement, but we would not be able to say that it will do so in a predictable fashion because Tarnow’s result was a retrospective case presentation featuring a single implant and such gap resolution is not expected to occur regularly in a spontaneous fashion, especially when the gap is large. And if employing a gap management protocol promotes consistently favorable results despite the fact that favorable results might otherwise sometimes occur without intervention, the prudent thing for us to do to achieve the greatest success is to intervene. Of course, if there were some potential for greater overall harm on either the site-level or the patient-level, that would be an entirely different situation, but as of the writing of this review, the literature does not indicate that any such potential exists.

Clinical Application

In proposing guidelines for clinical practice, one must avoid falling into one of two traps when making recommendations, each located at opposite ends of the therapeutic spectrum. The first trap is that of unjustified stringency, while the second is that of unsubstated leniency.

Some needlessly resist shifts in clinical paradigms at the price of failing to provide their patients with the most contemporary avenue of treatment, while others take the publication of successful case reports as solid and compelling evidence to change the way they practice, despite either a complete lack of statistical significance or any other number of confounding issues, such as extremely small sample size or an instance of retrospective analysis that is claimed to be such a good idea ex post facto.

With these two dangers in mind, I suggest the following guidelines for immediate peri-implant gap management:
1) When treatment planned for extraction (and potential immediate implant therapy), teeth should be extracted in the mostatraumatic manner possible. Forces should be applied withlow velocity and high duration to minimize trauma to the adjacent hard tissues, and the sectioning of multi-rooted teeth ought to beemployed to prevent damage to facial plates and furcal bone, especially for molars.

2) Unless deemed absolutely necessary, such as when ridge augmentation is being employed simultaneously with implant placement, flaps should be avoided, and especially in the anterior where the facial bone is often less than 1mm thick.

3) Implants should not be intentionally malpositioned or misaligned in close proximity to the facial plate in order to decrease the effective horizontal dimension of the peri-implant gap. Rather, the position and angulation of the fixture should be chosen primarily by determinants such as the need to achieve adequate primary stability and to be in line with an appropriately recognized restoratively-driven plan.

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Author’s Bio

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Dr. Rosenbach is currently on faculty at both the GPR at Woodhull Medical Center and the postgraduate periodontal department at Lutheran Medical Center, as well as in private practice in both NY and NJ. He serves as the head of project for WikiProject Dentistry on Wikipedia. Dr. Rosenbach lectures regularly on topics related to periodontics, implant dentistry and adjunctive surgical procedures. He can be reached at RosenbachPerio@yahoo.com.

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1. The primary concern related to the immediate peri-implant gap is:
   a. its potentially deleterious effect on primary stability.
   b. the potential for it to contribute to aesthetic and/or functional compromise.
   c. how it will help the clinician to plan the implant-supported restoration.
   d. there is no concern in human patients.

2. Although gaps can occur on any side of an immediate implant, the focus is often on:
   a. the palatal, because there is often an excess keratinized tissue on the palate.
   b. the lingual, because of the potential danger to the lingual nerve during implant placement.
   c. the interproximal, because oral hygiene procedures are more difficult to carry out between teeth.
   d. the facial, because contemporary dentistry dictates that the facial aspect of implant-supported restorations be in aesthetic and functional harmony with the adjacent hard and soft tissues.

3. Although not entirely representative of human studies, dog studies are deemed to be considerably relevant, and have the benefit of:
   a. being able to provide a model in which implants never exhibit bone loss.
   b. being able to provide a model in which there is no saliva to contaminate our results.
   c. being able to provide us with ample opportunity for histologic study.
   d. being able to provide us with a source for xenograft particulate bone material.

4. The percentage of surface area of the implant fixture intimately fused to vital bone is called:
   a. bone-to-implant contact.
   b. primary stability.
   c. flux capacitation.
   d. osseoincorporation.

5. Even when clinical bone fill is apparent, histology must be performed to absolutely confirm osseointegration because:
   a. gaps may have healed with apparent clinical bone fill but a microscopic seam of fibrous connective tissue may exist between the bone and the fixture.
   b. radiographs often magnify the implants so that small defects appear much larger than they really are.
   c. the use of periodontal probes is contraindicated for use with dental implants.
   d. osseointegration often reverses itself in the dog model and histology is the only way to confirm that this hasn’t happened.

6. One of the studies reviewed compared gap resolution in relation to machined surfaces versus roughened surfaces in a dog model and found that the gaps resolved with:
   a. integrated bone against both the machined and roughened surfaces.
   b. a fibrous seam against both the machined and roughened surfaces.
   c. integrated bone against the roughened surfaces and a considerable fibrous seam against the machined surfaces.
   d. none of the above.

7. Which dimension of the immediate peri-implant gap was completely ignored by a recent review paper highlighted in this review?
   a. the vertical height of the defect, from the implant platform to the most coronal aspect of bone contact.
   b. the vertical height of the defect, from the implant platform to the osseous crest.
   c. the horizontal width of the defect, measured mesio-distally and parallel to the tangent of the platform’s circumference.
   d. the horizontal width of the defect, along a line drawn from the contact points of the adjacent teeth.

8. According to the author, the most difficult part of doing an excellent job of reviewing the literature is:
   a. obtaining all the relevant papers because multiple journal subscriptions can be very costly.
   b. reading all of the papers because it’s very time consuming.
   c. knowing which data are able to be compared to which other data because different authors utilize different methods of investigation that are often incomparable.
   d. being able to modify one’s manner of practice because the new way will be different from how he or she was initially trained.

9. A recent review described two dimensions of the peri-implant gap as being:
   a. a vertical dimension and a horizontal dimension.
   b. two horizontal dimensions.
   c. a mesial dimension and a distal dimension.
   d. a buccal dimension and a palatal dimension.

10. Titanium-plasma sprayed (TPS) implants are not used as much as they used to be because:
    a. they were very expensive and cheaper alternatives became available.
    b. they worked very well in the dog model but didn’t seem to integrate in humans.
    c. it was later found that the titanium plasma became too hot during implant placement and burned the bone, subsequently resulting in necrosis.
    d. none of the above.

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Gap Management Around Immediate Implants
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