Rationale for Mini Dental Implant Treatment

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Mini dental implants can be used to support crowns and partial and complete dentures in compromised edentulous sites. Lack of bone width or site length may be treated with mini implants. Mini implants have less percutaneous exposure and displacement that may reduce complications. Nonetheless, mini implants transmit about twice the load to the supporting bone, and thus, control of occlusal loading is important. In fixed prosthetics, rounded flat cusps, splinting, implant protective occlusal schemes, and placement only in dense bone sites are features of successful mini implant treatment. With removable prosthetics, multiple mini implants may be needed for appropriate retention and load resistance. Maxillary lateral incisor and mandibular incisor sites may be best suited for mini implant treatment. However, past research on dental implants has been directed at standard sized implants. While mini implants are indeed dental implants, they behave somewhat differently under functional load, and the clinician should be circumspect and very judicious in their use. This article is a mini review and not a systematic review. The topics covered are not pervasive because each would require a monograph or textbook for a complete discussion.

Key Words: dental implant, occlusal load, osseous resistance, off-axial load, percutaneous exposure

INTRODUCTION

Mini implant dental treatment has become mainstream over the past several years.[1] This modality can provide a better quality of life for many patients who in the past may have been considered unrestorable. Recent research has found that small-diameter implants may be as successful as standard-diameter (>3.0 mm) implants when placed appropriately.[1,2]

Although there is no classification criterion for mini implants, generally an implant with a diameter equal to less than 3 mm can be considered a mini implant.[1]

Since economics may limit some patients' ability to afford treatment with standard-diameter implants, mini implant treatment may be affordable for these patients. Mini implants and the associated instrumentation are much less expensive than standard-diameter implants, resulting in a cost savings that makes treatment much more affordable.

Some patients have adverse feelings regarding grafting procedures. Mini implants may be able to support prosthetics in an atrophic site without osseous or soft-tissue grafting.

Some clinicians may fear extensive surgical procedures. Mini implants may be placed without raising a mucoperiosteal flap is some conditions, making the procedure less complex. Nonetheless, an appropriate referral should be made if the treatment requires such.

Some patients retain an inordinate fear of dentistry. Because mini implant treatment can be much less invasive, it may alleviate that fear. In addition, mini implants are much less invasive, and thus treatment with mini implants may facilitate or enable treatment for frail or medically compromised patients. Nonetheless, mini implants cannot be placed in all osseous sites.

In this article, a short review of the available evidence is presented to delineate clinical parametric guidelines for mini dental implant treatment. This work cannot be a true systematic review or meta-analysis because the review criteria are not met.

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https://doi.org/10.1563/aaid-joi-D-19-00317

REVIEW OF THE LITERATURE

The Cochrane Library, PROSPERO, and PubMed were searched using the following search terms: mini implant OR small diameter implant AND systematic review. There were no results in the Cochrane Library because of the stringent criteria. The PROSPERO search yielded 3 articles in progress, 2 dealing with mandibular overdentures and 1 on pain on insertion of mini implants (Table 1). The PROSPERO articles had not yet passed review. A total of 85 articles were identified in PubMed. Articles on orthodontic temporary anchorage devices were eliminated because these implants are under a minimal load of 2–5 N, used in the short term, generally very narrow and short, and not used for prosthetics. Articles on orthopedics, gynecology, pediatric dentistry, and short implant length were eliminated as well. Additional articles were eliminated for patient-reported outcomes, general reasons for implant failures, implants in children, technique issues, and ectodermal dysplasia. After these eliminations, 10 articles remained, which were reviewed for appropriate inclusion (Table 2). Most of these are evidence reports on mandibular overdenture outcomes, which are favorable.

During the review process of this work, an article was published that discussed the use of narrow-diameter implants in "permanent" dental prosthetics and had not yet been entered into the search libraries.[13] Nonetheless, only anterior single crowns and overdentures were covered. There was no coverage of fixed partial or complete dentures. The evidence for fixed mini implant–supported prosthetics is severely lacking.

There were no high-level credible studies on mini implants

TABLE 1

PROSPERO search

Lead Author	Topic	Card No.	Submission Date
Hassan	Mandibular overdentures	42017068623	04/06/2017
Elsadek	Mandibular overdentures	42017063904	07/04/2017
Paiva	Pain and discomfort	42017059031	10/03/2017

supporting fixed prostheses. Nonetheless, the clinician may use mini implants to support fixed prostheses based on known physiologic parameters. These parameters are based on mechanical physiologic principles for successful outcomes and are discussed herein. However, the fact remains that the use of mini implants requires significant clinical experience and training, and these implants cannot be placed any every anatomical site.

Osseous Atrophy

After extraction, the bone atrophies and bone volume decreases. Generally, the facial cortical wall migrates to the lingual cortex, whereas the lingual cortex does not remodel to the facial wall.[14] This remodeling sequence results in a decrease in medullary bone and brings the facial and lingual cortices in close proximity. When the atrophy is severe, the 2 cortices can be almost in contact with one another. This can create an optimal bone condition for mini implant placement. The 2 cortices are generally 1.5- to 2-mm thick.[14] A mini implant placed in such a situation is provided dense cortical bone support along its full length (Figures 1 through 3). Thus, atrophic bone may not require extracortical grafting or ridge splitting and expansion to provide enough bone volume and density for appropriate mini implant placement and adequate osseous resistance to loading.

Density Variation in Edentulous Sites

After the extraction bone heals and remodels, these sites can have variable bone densities that may not impart adequate support for mini implants. The denser the bone, the better support for a mini implant. Note the various radiographic densities in the panoramic orthopantograph (Figure 4).

Flapless Versus Flapped Placement

Mini implants are well suited for flapless placement, but the clinician should be well aware of the underling osseous contour to prevent dehiscence, fenestration, or malposition.[15] Generally, the clinician can visualize bone contour on cone-beam computerized tomography (CBCT) or by ridge mapping.[16] Any defect encountered should be addressed before or during the implant placement. A defect can be grafted before implant placement if deemed necessary or possibly at implant placement time, but this would require flap access to the underlying bone.

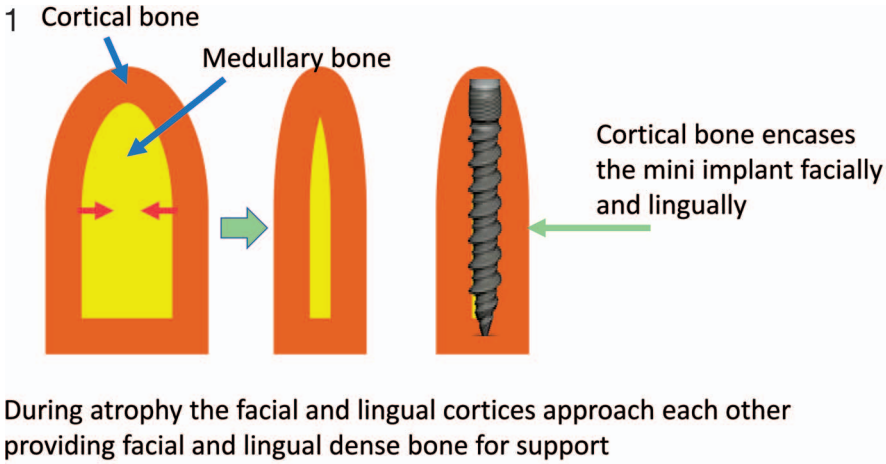
A site with atrophic bone that presents a knife edge may be reduced to provide a wider crest site for easier placement (Figure 5). A mucogingival flap can be raised in areas of full thickness at the crest and partial thickness at the facial. (Generally, a lingual flap may not be necessary for the experienced clinician.) The crestal bone is now exposed for visualization and reduction if necessary, and the facial submucosa is available for engaging a suture that holds the flap intimately against the submucosa.

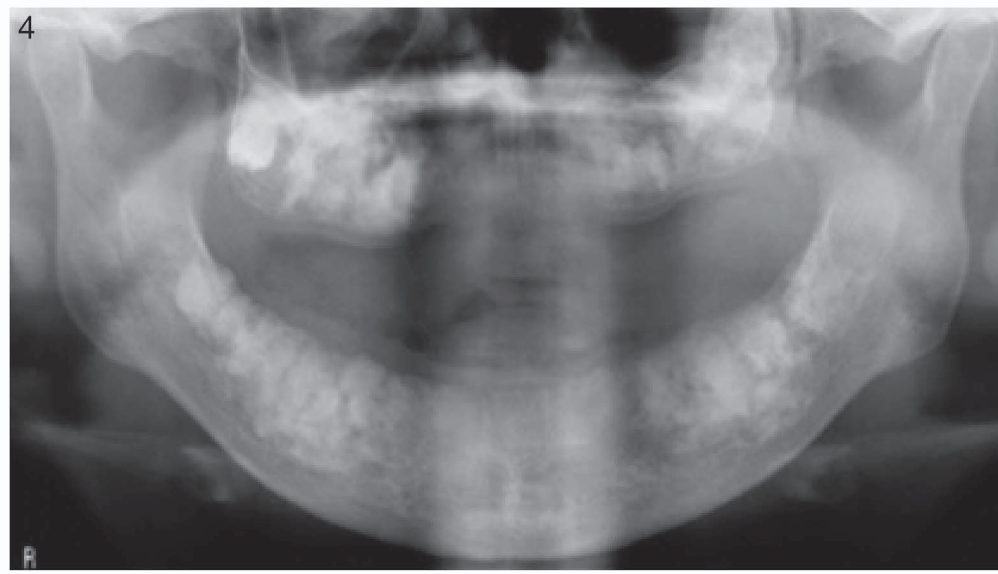
Flapless placement is generally associated with better healing and fewer complications then flapped procedures are.[15] Nonetheless, there needs to be an assessment of the underlying osseous contour. This can be done by CBCT or ridge mapping. A ridge should be wide enough to accept the implant diameter and at least 1.8-mm facial and lingual cortices.[17] Thus, the thinnest acceptable ridge may be 3.6-mm plus the diameter of the proposed implant, unless the ridge is to be split and expanded.

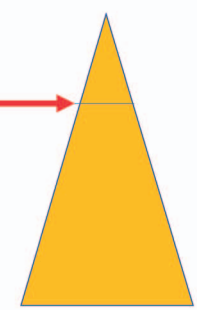
TABLE 2

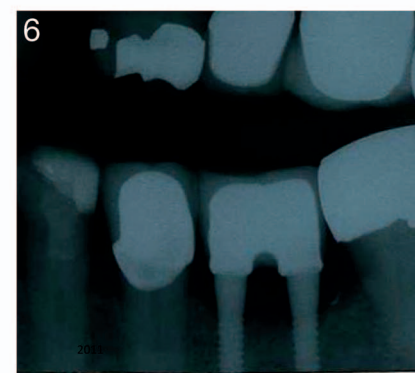
List of accepted systematic reviews

Systematic Review	Year	Modality	Comments	Conclusions
Schiegnitz et al[3]	2018	Fixed and removable	High risk for bias	Long-term data are missing
Marcello-Machado et al[4]	2018	Mandibular overdentures	High survival and success rates	Adequate clinical behavior
Park et al[5]	2017	Mandibular overdentures	High survival rates Significant satisfaction rates	Predictable results
Sivaramakrishnan et al[6]	2017	Patient satisfaction Overdenture comparison	Limited data available	Good patient satisfaction as compared with standard implants
Lemos et al[7]	2017	Overdentures	High survival rates and satisfaction	Alternative to standard implants
de Souza Batista et al[8]	2018	Mandibular overdentures	Most placed flapless High survival rates	Improved function Viable and safe
Klein et al[9]	2014	Fixed and removable <3.5 mm	Same survival as standard implants	High survival rates
Jawad et al[10]	2019	Mandibular overdentures	Excellent survival rates	Reasonable alternative
Bidra et al[11]	2013	Overdentures	Dearth of evidence No comparison studies High survival rates	True survival unknown Terminology is not definitive
Kim et al[12]	2017	Mandibular overdentures	Better function High failure with short minis Use for <6 mm bone width	4 or more mini implants >10-mm bone height needed









Figures 1–6. Figure 1. After an extraction, the bone remodels and the cortices approach each other. The facial cortex generally approaches the lingual cortex. **Figure 2.** Cone-beam computerized tomography image of a severely atrophic edentulous site. **Figure 3.** The atrophic cortices can provide dense osseous support for mini implants. **Figure 4.** After tooth extraction, bone may remodel and produce different densities of bone. **Figure 5.** A peaked atrophic ridge may be reduced with a bone burr to produce a flat, wider surface for a mini implant osteotomy. **Figure 6.** Two mini implants may provide enough support for a molar site.

Angiogenesis and Osteogenesis

Because the displacement of mini implants is small, there may less obstruction to angiogenesis and osteogenesis. One study in dogs found that large-diameter implants were associated with less bone formation.[18] Thus, larger-diameter implants may impede new bone formation and small-diameter implants less so. Bone remodeling may be inhibited as well.[19]

Frictional Heat During Mini Implant Placement

One study found that there is substantial heat imparted to bone during the seating of mini implants in dense bone.[20] Because the thermal conductivity of titanium is about 70 times that of bone, the implant will absorb any frictional heat. However, a large implant has enough volume to absorb the heat and keep it away from the bone. A mini implant does not have the volume of a large-diameter implant and thus becomes much hotter, releasing the heat back into the surrounding bone.[20]

Irreparable osseous heat damage occurs after a 54°C temperature held for 2 minutes.[21–23] Since the implant remains in the bone, the hot implant can potentially damage the surrounding bone, which leads to an early failure.

The implant drill may feel hot after an osteotomy, but the bone is not.[24] An osteotomy drill is removed from the site, and the heat is taken away as well. Thus, during mini implant placement in dense type 1 bone, this author recommends irrigation of the implant to prevent any osseous thermal damage.

Blood and tissue fluid can provide lubrication during implant seating, and vasculature can remove any generated heat.[25] In the anterior mandible, the blood supply mostly comes from the periosteum from the facial artery.[26] The bone in the anterior mandible can be dense type 1 bone, which may create significant frictional heat. If the vasculature is not significant, there is not much tissue fluid, and the bone is dense, there may be significant heat generated from seating mini implants. Thus, when seating mini implants in dense bone in the anterior mandible, irrigation should be provided to prevent undue heat damage to the bone. In addition, the rate of rotation should less than 12 rpm, and there should "rest stops" during seating to prevent undue heating.

Percutaneous Exposure

Percutaneous exposure is much smaller with mini implants. The circumference of a 4-mm implant is 12.56 mm, whereas that of a 2.5-mm implant is 7.85 mm. Empirically, the smaller circumference may reduce peri-implant epithelial attachment complications, such as implant peri-mucositis or peri-implantitis. Long-term complications may be reduced as well.

Just as with standard-diameter implants, adequate attached tissue or immovable mucosa should surround mini implants.[27] Augmentations can be accomplished via a multitude of techniques, including grafts that are free gingival, subepithelial, dermal allograft, and others.

Occlusal Loading

Because mini implants are very narrow, the implant profile and displacement are smaller and thus impart a much larger load on the supporting bone. An off-axial load will impart 1.5–2.5 times the load imparted by a larger standard sized implant.[28] Thus, occlusal loads must be controlled to prevent an overload and subsequent failure. Narrow flat occlusal tables, rounded cusps, splinting, and implant-protective occlusal schemes are indicated. An anterior-guided scheme for fixed restorations or lingualized occlusal schemes for removable dentures may be best. An appropriate occlusal scheme in which the implants are protected from off-axial loads is extremely important.

The surface area of two 2.5-mm mini implants is about equal to the surface area of a 5.7-mm implant, so 2 closely placed mini implants may be adequate to provide adequate osseous resistance to occlusal loads (Figure 6). Two mini implants may be best used between 2 adjacent teeth to alleviate the functional loading. Nonetheless, the prudent clinician may test the patient for maximum bite force capability.[29] There are 3 companies that sell oral bite load capacity devises: KUBE, FUTEK, Tekscan. Any patient with an excessive capability may require an appropriately sized implant to resist occlusal loading and an occlusal scheme to protect from off-axial loads.

Natural teeth can be part of an arch being restored with implant-supported crowns or fixed partial dentures. Natural teeth intrude up to 250 μm under functional loading.[30] Implants may intrude up to 8 μm.[30] If the implant-supported prosthetics are not provided occlusal relief for this discrepancy, there is a risk of overloading the supporting implants. Occlusal relief up to 100 μm may be indicated to ensure a long-term favorable outcome.

Mini implants are subject to lateral, off-axial loading, which may cause metal fatigue. One study placed horizontal 200 N cyclic loads on 2.5-mm mini implants.[31] Only a minority of implants fractured after over 1 million cycles. The 200 N directly lateral load is excessive and unlikely in clinical situations. Nonetheless, the barrier to treatment success is not the strength of the implant but the ability of the supporting bone to resist the occlusal loading.

Opposing Removable Complete Dentures

The bite load capability of patients with complete dentures is much lower than dentate patients.[32] Thus, these patients may not be able to overload a mini implant–supported crown or fixed partial or complete denture. Nonetheless, occlusal load control can be instituted by using a lingualized or flat zero-degree occlusal scheme.

Two-Piece Systems

One-piece narrow-diameter implants do well in appropriate sites, but those with screw-retained abutments appear to suffer from a high rate of abutment screw fracture.[33] When a 180 N load was repeatedly placed against these types of implants, most of the abutment screws fractured under this load. This may be important in the anterior maxilla, where the mandibular anterior teeth would occlude directly off-axially to maxillary implant supported crowns. Nonetheless, patients who are not capable of generating such a load may not be subjected to abutment screw fracture.

Immediate Placement

Mini implants can be placed in immediate extraction sites with an appropriate grafting procedure (Figures 7 through 9).[34] Appropriate grafting procedures should be used just as with standard-sized implants. Coverage of the surgical site with barrier membranes or primary closure may be best.[34]

Mini Implants Retaining Removable Dentures

Mini implants can successfully retain removable dentures, but implant retention will not "save" a case with an ill-fitting denture or inappropriate occlusal scheme. The removable denture should have a well-fitting intaglio and be stable. A lingualized or zero-degree flat occlusal scheme may be best for removable dentures.[35]

Because mini implants retaining removable dentures are immediately loaded, these parameters should be met before implant placement. For immediate loading of mini implants retaining removable dentures, the seating torque should be a minimum of 32 Ncm.[36]

In general, the retention of 4 mini implants is not as retentive as a 2-implant Locator-type scheme (Figure 10). More than 4 mini implants can be placed for increased retention, but anatomical conditions may prevent additional implant placements.

Placing multiple implants in the maxilla for retention of a complete maxillary removable denture can be done. Maxillary bone generally may not be appropriate for mini implant treatment. Less dense bone can be compressed. The clinician should seriously consider placing as many implants as space and anatomy allow. This distributes the load over as many implants as possible. While an implant length does not contribute as much load resistance as an implant diameter, every advantage should be taken, so it may be best to use as long an implant as anatomically possible, and it may be best to space the implants at 8 mm.[37]

The clinician should evaluate each implant for initial stability. The stability should be rock hard. This can be done by tapping the implant while the clinician senses the stiffness and stability; commercial stability devices are also available. The appropriately placed mini implant should feel rock-hard solid. The clinician should not expect a non–rock-hard solid implant to tighten with bone healing. Commercially, available stability measurement devices may have not been calibrated for mini implants, so the clinician should consult the manufacturer. Any implant that is not at high stability should be removed and repositioned in a site with more dense bone.

Fixed Crowns and Partial Dentures

Mini implants can support a single crown and partial and complete fixed restorations, but the occlusal loading must be controlled (Figures 11 through 16). Off-axial forces may cause overloading and failure.[38,39]

Standard, off-the-shelf coping abutments can be used in a telescoping technique for fixed crowns and partial dentures. The abutments are placed on the implants, temporarily linked together with fast-set bis-acryl to prevent movement and picked up in an overimpression for direct laboratory fabrication of a telescoped crown or fixed retainers.

Complications

Systemic factors can influence the clinical outcomes of dental implant treatment, both mini and standard.[40] However, many studies have shown that patients with well-controlled diabetes can undergo successful implant treatment. Nonetheless, long-term outcomes may be fraught with local complications because of the disease itself or the medications used to treat that disease.[40,41] Implants in these patients should be carefully monitored for soft-tissue and bone levels. Because mini implants are so much less invasive with low percutaneous exposure and displacement, there may be less risk for long-term complications in these patients. A thorough health history is needed to make the clinician aware of any adverse systemic conditions and the associated medications that may affect healing and bone remodeling.

Adequate attached tissue or immobile soft tissue is needed to prevent muscle pulls from stressing the epithelial attachment.[42] Bone loss can occur if there is inadequate protection from this. Late loss of attached or immobile tissue can occur and be prevented or corrected with an augmentation procedure.

This author found no reports of fracture on seating mini implants or any other implants. Nonetheless, an anecdotal radiograph demonstrates that it may be possible to fracture a mini implant if it is fatigued. After several attempts at seating, a mini implant did indeed fracture (Figure 17). It may be best to discard a mini implant after 3 attempts at seating in very dense type 1 bone. Alternatively, it may be best to redrill an osteotomy if the implant does not readily seat to the desired depth on the first attempt.

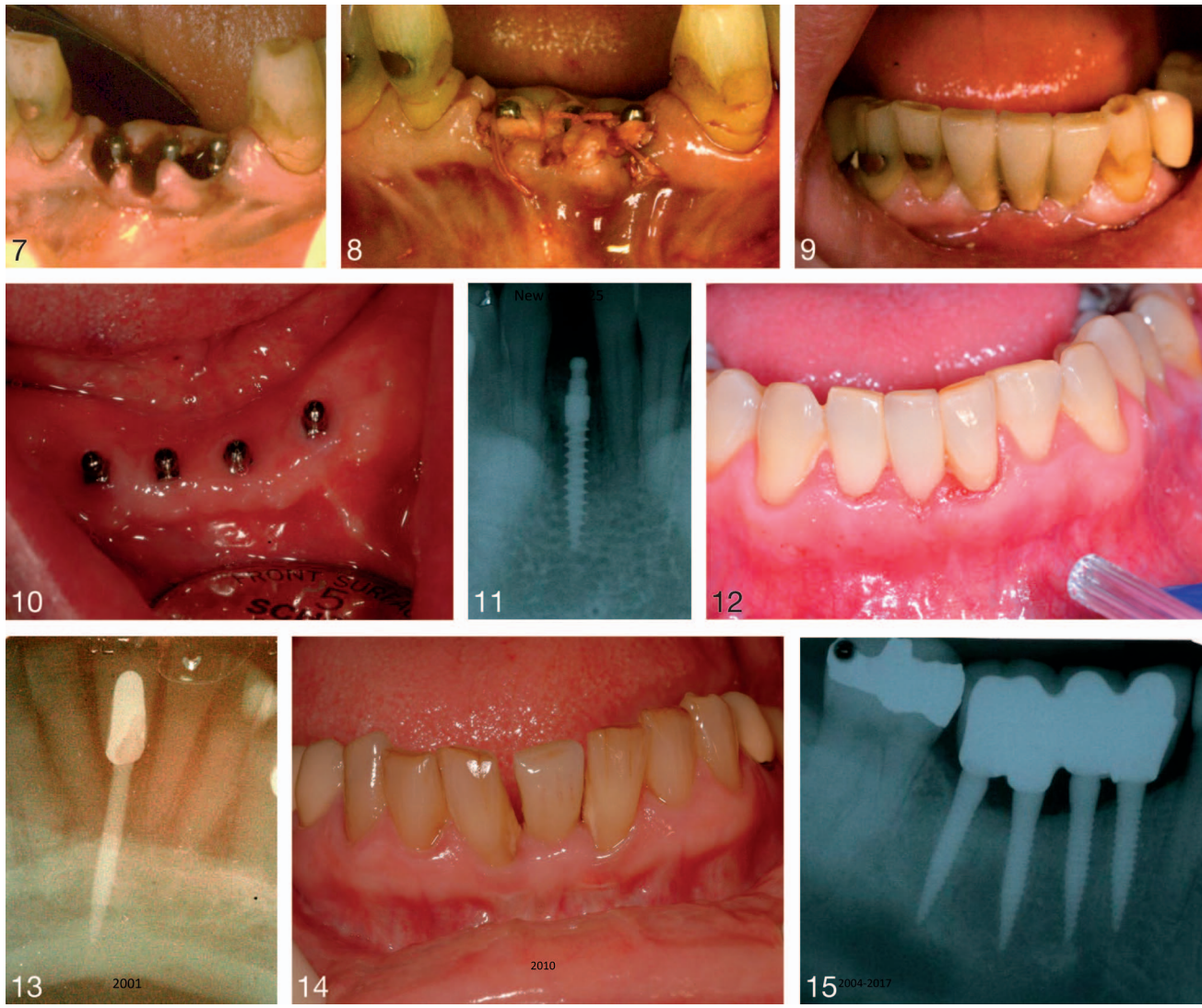
After some time of function with implant-supported crowns and dentures, the mesial natural tooth may move to the mesial, creating a small gap. This may cause caries to form just below the previously established interproximal contact area (Figure 18). Of course, this should be restored with conventional restoratives and the patient made aware of this phenomenon.

Mini implant–supported crowns and dentures should be cemented with insoluble luting agents. Resin cements are generally the appropriate choice. Soluble cements should be avoided because of the potential for retainer loosening. The crown or fixed denture could loosen from loss of purchase. Crowns can be recemented, but if one retainer of a fixed denture loosens from cement dissolution, then the still-cement-retained retainer(s) may undergo repeated rotation or lifting under occlusal loading and cause a loss of integration or overload and failure (Figure 19).

Any implant placed in the anterior mandible can severe the sublingual artery, which can subsequently retract into the floor of the mouth, creating a significant hematoma.[26,43]

Food and Drug Administration

The US Food and Drug Administration in 2010 classified 510(k) mini dental implants for "long term use."[43] Thus, mini dental



Figures 7–15. Figure 7. Immediately after extractions, mini implants were placed. **Figure 8.** Mini implants immediately placed were grafted with particulate allograft and covered with dermal allograft; any resorbable barrier membrane will suffice. No flap was raised. **Figure 9.** Splinted crowns supported by mini implants after 2 months of service. **Figure 10.** Four mini implants are generally adequate retention for a complete removable overdenture. **Figure 11.** A single mini implant may support a single crown in the anterior mandible where occlusal loads are less, and space may be limited. **Figure 12.** A clinical view of the mini implant–supported crown. **Figure 13.** A year 2001 radiograph of a single mini implant in the anterior mandible. **Figure 14.** A 2010 image of the implant-supported crown placed in year 2001. The crown is still in situ at the time of this writing. **Figure 15.** A radiograph of multiple mini implants supporting splinted crowns in the posterior jaw where occlusal loads are increased.

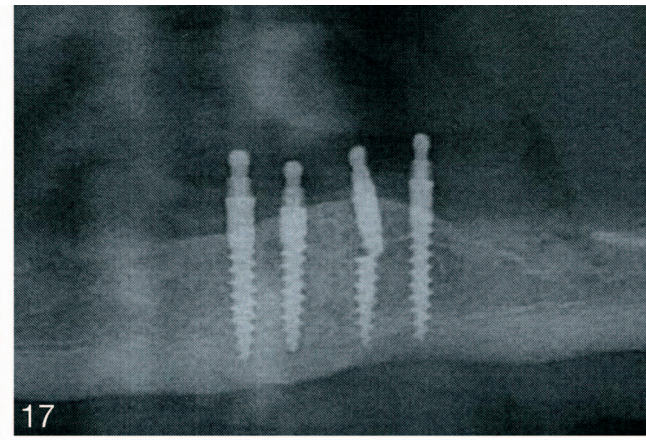
implants may be used to support or retain dental prostheses. With off-label use, mini implants may be used with a guarded prognosis.

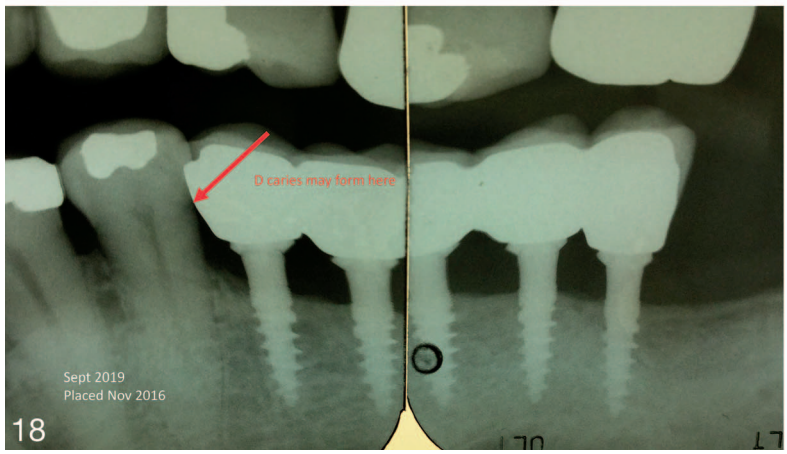
Conclusions

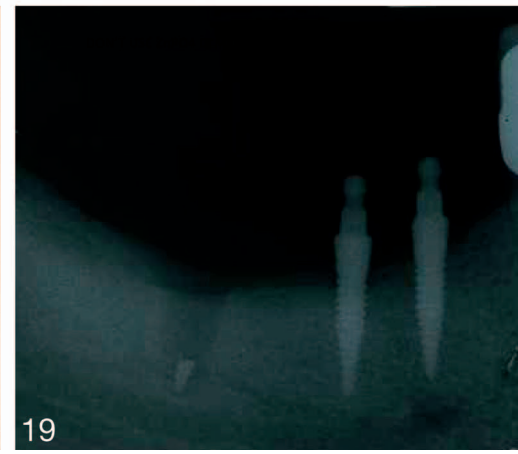
Because most research in oral implantology has been directed at standard-sized implants, there are large lacunae in the knowledge base for mini implant treatment.[43] There needs to be research directed at mini implant technology. Although there are similarities between mini and standard-diameter implants, the clinical performance of small-diameter implants in oral rehabilitation needs to be elucidated.

Mini implants cannot be placed in just any anatomical site. The clinician needs to be aware of the osseous and soft-tissue features of a prospective site, the patient's bite force capability, esthetic expectations, appropriate occlusal schemes, and treatment of complications. Complications can occur and should be addressed early.

Indications for mini implant treatment include inadequate site length or width, atrophic bone, medical issues, fragility, financial hardship, patient declination of grafting, and patient fear of surgery. Maxillary lateral incisor and mandibular incisor sites may be most amenable for mini implant restoration because of space limitations, favorable bone density, and decreased occlusal force impartment.







Figures 16–19. Figure 16. A clinical image of the multiple mini implants supporting splinted crowns. **Figure 17.** An anecdotal image of a mini implant that fractured after several attempts at seating. Metal fatigue may have caused the fracture. Redrilling the osteotomy may relieve the osseous resistance and allow appropriate seating. **Figure 18.** Teeth may drift mesially and open the interproximal contact between the implant-supported crown and the tooth. Caries can occur inferior to the prior contact area and should be restored to remove caries and restore the contact area. **Figure 19.** Insoluble cements should be used to retain mini implant retainers. Soluble cement dissolution may occur and subsequently cause an overload of the retained retainers, resulting in implant failure.

Caveat

Multiple randomized controlled trails have been conducted with standard-sized dental implants. Mini implants have not enjoyed such attention. There is a dearth of randomized controlled trials on the clinical behavior of mini implants. Mini implants may not withstand an occlusal load as well as standard-sized implants, and this should be addressed by using multiple implants, limiting their use to dense bone, and controlling the occlusal loading. Therefore, the clinician should use prudent clinical judgment in the use of mini dental implants. This article is a short review, and the topics covered are not in depth, as each would require a monograph or textbook for a complete discussion.

Guidelines for Mini Implant Treatment

- Be aware of the osseous contour before placement, especially for flapless treatment.
- Place only in type 1 and 2 bone sites, and be certain of excellent initial stability.
- Irrigate during seating to prevent overheating.
- Ensure adequate soft-tissue protection of the epithelial attachment with attached tissue or immovable mucosa.
- Control off-axial loading with an appropriate occlusal scheme and occlusal design.
- Maintenance is imperative.
- Complications should be addressed expeditiously.

Abbreviation

CBCT: cone-beam computerized tomography

References

1. Flanagan D, Mascolo A. The mini dental implant in fixed and removable prosthetics: a review. *J Oral Implantol*. 2011;37(spec no):123–132.

2. Sohrabi K, Mushantat A, Esfandiari S, Feine J. How successful are small-diameter implants? A literature review. *Clin Oral Implants Res*. 2012;23: 515–525.

3. Schiegnitz E, Al-Nawas B. Narrow-diameter implants: a systematic review and meta-analysis. *Clin Oral Implants Res*. 2018;29(Suppl 16):21–40.

4. Marcello-Machado RM, Faot F, Schuster AJ, Nascimento GG, Del Bel Cury AA. Mini-implants and narrow diameter implants as mandibular

overdenture retainers: a systematic review and meta-analysis of clinical and radiographic outcomes. *J Oral Rehabil*. 2018;45:161–183.

5. Park JH, Lee JY, Shin SW. Treatment outcomes for mandibular mini-implant-retained overdentures: a systematic review. *Int J Prosthodont*. 2017; 30:269–276.

6. Sivaramakrishnan G, Sridharan K. Comparison of patient satisfaction with mini-implant versus standard diameter implant overdentures: a systematic review and meta-analysis of randomized controlled trials. *Int J Implant Dent*. 2017;3:29.

7. Lemos CA, Verri FR, Batista VE, Júnior JF, Mello CC, Pellizzer EP. Complete overdentures retained by mini implants: a systematic review. *J Dent*. 2017;57:4–13.

8. de Souza Batista VE, Vechiato-Filho AJ, Santiago JF Jr, et al. Clinical viability of single implant-retained mandibular overdentures: a systematic review and meta-analysis. *Int J Oral Maxillofac Surg*. 2018;47:1166–1177.

9. Klein MO, Schiegnitz E, Al-Nawas B. Systematic review on success of narrow-diameter dental implants. *Int J Oral Maxillofac Implants*. 2014; 29(Suppl):43–54.

10. Jawad S, Clarke PT. Survival of mini dental implants used to retain mandibular complete overdentures: systematic review. *Int J Oral Maxillofac Implants*. 2019;34:343–356.

11. Bidra AS, Almas K. Mini implants for definitive prosthodontic treatment: a systematic review. *J Prosthet Dent*. 2013;109:156–164.

12. Kim HY, Lee JY, Shin SW, Bryant SR. Attachment systems for mandibular implant overdentures: a systematic review. *J Adv Prosthodont*. 2012;4:197–203.

13. Froum S, Natour M, Cho S-C, Yu PYC, Leung M. Expanded clinical applications of narrow-diameter implants for permanent use. *Int J Periodontics Restorative Dent*. 2020;40:529–537.

14. Flanagan D. A comparison of facial and lingual cortical thicknesses in edentulous maxillary and mandibular sites measured on computerized tomograms. *J Oral Implantol*. 2008;34:256–258.

15. Flanagan D. Flapless dental implant placement. *J Oral Implantol*. 2007;33:75–83.

16. Flanagan D. A method for estimating preoperative bone volume for implant surgery. *J Oral Implantol*. 2000;26:262–266.

17. Spray JR, Black CG, Morris HF, Ochi S. The influence of bone thickness on facial marginal bone response: stage 1 placement through stage 2 uncovering. *Ann Periodontol*. 2000;5:119–128.

18. Jimbo R, Janal MN, Marin C, Giro G, Tovar N, Coelho PG. The effect of implant diameter on osseointegration utilizing simplified drilling protocols. *Clin Oral Implants Res*. 2014;25:1295–1300.

19. Flanagan D. Osseous remodeling around dental implants. *J Oral Implantol*. 2019;45:239–246.

20. Flanagan D. Heat generated during seating of dental implant fixtures. *J Oral Implantol*. 2014;40:174–181.

21. Eriksson A, Albrektsson T, Grane B, et al. Thermal injury to bone: a vital microscopic description of heat effects. *Int J Oral Surg*. 1982;11:115–121.

22. Eriksson AB, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: a vital microscopic study in the rabbit. *J Prosthet Dent*. 1983;50:101–107.

23. Eriksson RA, Albrektsson T, Magnusson B. Assessment of bone viability after heat trauma: a histological, histochemical and vital microscopic study in the rabbit. *Scand J Plast Reconstr Surg*. 1984;18:261–268.

24. Flanagan D. Osteotomy irrigation: is it necessary? *Implant Dent*. 2010;19:241–249.

25. Paul A, Narasimhan A, Das SK, Sengupta S, Pradeep T. Subsurface thermal behaviour of tissue mimics embedded with large blood vessels during plasmonic photo-thermal therapy. *Int J Hyperthermia*. 2016;32:765–777.

26. Flanagan D. Important arterial supply of the mandible, control of an arterial hemorrhage, and report of a hemorrhagic incident. *J Oral Implantol*. 2003;29:165–173.

27. Batal H, Yavari A, Mehra P. Soft tissue surgery for implants. *Dent Clin North Am*. 2015;59:471–491.

28. Sallam H, Kheiralla LS, Aldawakly A. Microstrains around standard and mini implants supporting different bridge designs. *J Oral Implantol*. 2012;38:221–229.

29. Flanagan D. Bite force and dental implant treatment: a short review. *Med Devices (Auckl)*. 2017;10:141–148.

30. Paccini JV, Cotrim-Ferreira FA, Ferreira FV, Freitas KM, Cançado RH, Valarelli FP. Efficiency of two protocols for maxillary molar intrusion with mini-implants. *Dental Press J Orthod*. 2016;21:56–66.

31. Flanagan D, Ilies H, McCullough P, McQuoid S. Measurement of the fatigue life of mini dental implants: a pilot study. *J Oral Implantol*. 2008;34:7–11.

32. Ghani F, Likeman PR, Picton DC. An investigation into the effect of denture fixatives in increasing incisal biting forces with maxillary complete dentures. *Eur J Prosthodont Restor Dent*. 1995;3:193–197.

33. Hirata R, Bonfante EA, Anchieta RB, et al. Reliability and failure modes of narrow implant systems. *Clin Oral Investig*. 2016;20:1505–1513.

34. Flanagan D. Immediate placement of multiple mini dental implants into fresh extraction sites: a case report. *J Oral Implantol*. 2008;34:107–110.

35. Kawai Y, Ikeguchi N, Suzuki A, et al. A double blind randomized clinical trial comparing lingualized and fully bilateral balanced posterior occlusion for conventional complete dentures. *J Prosthodont Res*. 2017;61: 113–122.

36. Ostman PO, Hellman M, Sennerby L. Immediate occlusal loading of implants in the partially edentate mandible: a prospective 1-year radiographic and 4-year clinical study. *Int J Oral Maxillofac Implants*. 2008; 23:315–322.

37. Kosinski T. A sequential approach to implant-supported overdentures. *Dent Today*. 2016;35:68, 70–71.

38. Flanagan D. Mini implants supporting fixed partial dentures in the posterior mandible: a retrospective. *J Oral Implantol*. 2015;41:e138–e143.

39. Mascolo A, Patel PB. Splinted zirconia fixed partial denture supported by mini implants in the posterior mandible: a case study. *J Oral Implantol*. 2013;39:287–289.

40. Aghaloo T, Pi-Anfruns J, Moshaverinia A, Sim D, Grogan T, Hadaya D. The effects of systemic diseases and medications on implant osseointegration: a systematic review. *Int J Oral Maxillofac Implants*. 2019(suppl);S35–S49.

41. Mester A, Apostu D, Ciobanu L, et al. The impact of proton pump inhibitors on bone regeneration and implant osseointegration. *Drug Metab Rev*. 2019;51:330–339.

42. Gobbato L, Avila-Ortiz G, Sohrabi K, Wang CW, Karimbux N. The effect of keratinized mucosa width on peri-implant health: a systematic review. *Int J Oral Maxillofac Implants*. 2013;28:1536–1545.

43. Flanagan D. Implants and arteries. *J Am Dent Assoc*. 2004;135:566.