The Five Thread Guideline: A New Guideline for Predicting Primary Stability With Dental Implants

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INTRODUCTION

While industry best practices exist for sizing and positioning dental implants, too few guidelines are designed to aide clinicians in predicting primary implant stability in healed or fresh extraction sites. Predicting an implant's likelihood of surgical success is significant to the clinician for two reasons: (1) It determines the treatment options. If the conditions for a successful placement do not exist, alternative treatment plans, such as site development, should be considered. (2) Successful prediction of a surgical outcome maintains a good doctor-patient relationship, and communicating a low, medium, or high likelihood of surgical success keeps that relationship healthy.

The purposes of this paper was to present a new guideline—the five-thread guideline (5-TG), which recommends engaging a minimum of five implant cylinder threads in the native bone in order to better ensure primary stability—for predicting implant stability when planning dental implants in healed or fresh extraction sites, and describe three cases that benefited from implants placed using 5-TG principles.

CASE 1

A 53-year-old woman presented to the Stanley Dentistry (SD) clinic in Cary, North Carolina, with a chief complaint of a missing crown but no pain. Her oral exam revealed the crown on tooth #28 to be missing. A periapical radiograph (Figure 1) revealed that tooth #28 was previously treated with root canal therapy and little tooth structure remained above the level of the bone.

The patient's medical history revealed treatment for bipolar disorder, seasonal allergies, and hypothyroidism. Her current medications included lamotrigine, sertraline, aripiprazole, lisinopril, propranolol, levothyroxine, and liothyronine. Her past surgical history was unremarkable. She denied smoking or recreational drug use but admitted to social alcohol use.

Treatment options, as well as their risks and benefits, were discussed with the patient. These included crown lengthening, post buildup and new crown, extraction of tooth root, removable partial denture, three-unit fixed bridge, dental implant, and no treatment. The patient elected to have the tooth extracted and an implant placed.

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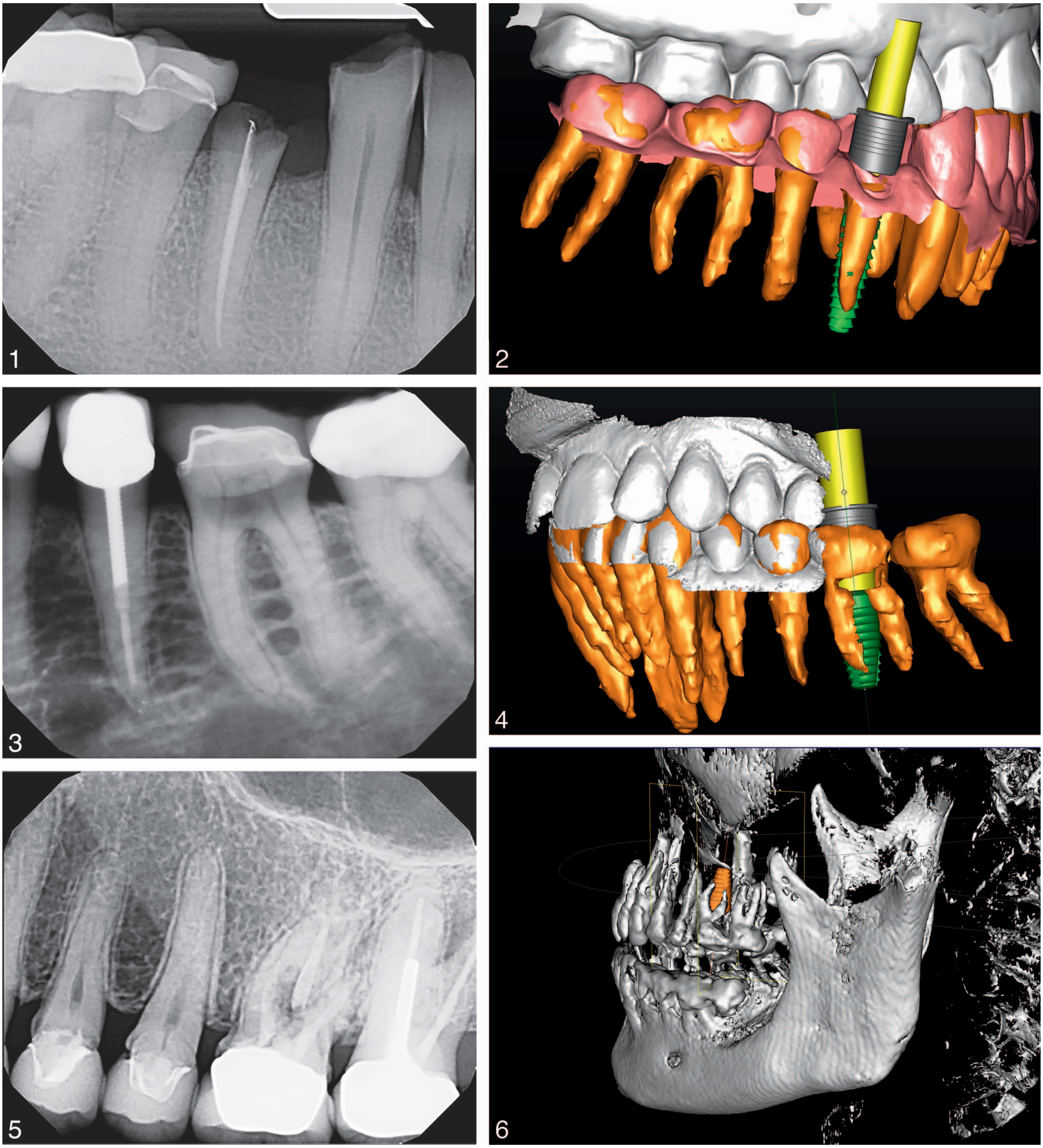
A 3-D cone beam computerized tomography (CBCT) scan and an optical scan were taken. These scans were aligned using SIMPLANT 17 implant planning software (Dentsply Sirona, York, Pa; Figure 2). The teeth were segmented from the CBCT data as a separate optical surface layer. An ideally sized implant was virtually placed, in keeping with well-known design guidelines like Tarnow's rule and the 3a2b rule.[1–3] To assist in visualizing the 5-TG, the bone volume was turned off and the layer with the surface rendering of the teeth was turned on. The teeth were rendered in a gold color, and the implant was colored green. The implant was virtually viewed from a variety of angles to determine if there were five full threads engaging the bone or if bi-socket or tri-socket stabilization existed. This virtual rendering (Figure 2) clearly showed three full threads apical to the socket as well as the entire mesial and distal of the implant contacting bone. With three full threads plus bi-socket engagement, the likelihood of primary stability was good, based on 5-TG principles.

The virtual plan was completed, and an order was placed for a fully guided tooth-supported surgical guide. The patient was informed of a good probability of extraction and immediate placement, and the surgical date was set. The agreed-upon treatment plan was atraumatic extraction of the tooth #28 root, immediate implant placement, and bone grafting of any gaps between the implant and socket walls. No provisionalization was necessary, since the surgical site was not noticeable in the patient's smile.

The dental team reviewed and agreed on the patient's treatment plan before beginning the procedure. The patient's vital signs were within normal limits. A topical anesthetic was placed, and an inferior alveolar nerve block was performed using 2% lidocaine with 1:100 000 epinephrine. The soft tissue was elevated with a #9 molt periosteal elevator, and the tooth was rotated out of its socket using an Ashe forceps. The socket was curetted and irrigated with copious amounts of normal saline solution. The tooth-borne surgical guide was evaluated for fit. The normal osteotomy drilling sequence was performed, and the implant was placed through the guide to a specified drill stop using a slow-speed handpiece. Good primary stability and no mobility of the implant were observed. Mineralized cortical and cancellous bone chips were hydrated in normal saline solution and packed into the buccal and lingual gaps between the implant and socket walls. A stock 3-mm-high healing abutment was placed. The graft was secured with high-viscosity PeriAcryl (GluStitch, Inc, Delta, British Columbia, Canada) and covered with petroleum jelly to prevent inadvertent attachment to the surrounding tissues. No hemostasis aids were needed.

Following the procedure, the patient was instructed to use



Figures 1–6. Figure 1. Periapical radiograph of case 1 patient's failing tooth #28. **Figure 2.** Three-dimensional cone-beam computerized tomography (3-D CBCT) reconstructed image of case 1 patient's failing tooth #28. Note three full threads apical to the socket and the entire mesial and distal of the proposed implant are engaging bone. Prognosis for immediate stabilization is good. **Figure 3.** Periapical radiograph of case 2 patient's tooth #19, revealing recurrent decay. **Figure 4.** A 3-D CBCT-reconstructed image of case 2 patient's failing tooth #19. By segmenting out the bone rendering, the relationship between the proposed implant (green) and intraradicular bone becomes clear. Five full threads apical to the socket and the entire buccal and lingual of the proposed implant are engaging bone. Prognosis for immediate stabilization is good. **Figure 5.** Periapical radiograph of case 3 patient's tooth #14, with radicular radiolucency noted. **Figure 6.** A 3-D CBCT-reconstructed image of case 3 patient's failing tooth #14. Note that five full apical threads and the entire mesial, distal, and buccal of the proposed implant are engaging bone. Five fully engaging threads plus tri-socket-stabilization provides a good prognosis for immediate stabilization.

prescribed antibiotics (amoxicillin 500 mg three times a day for five days) and chlorhexidine gluconate 0.12% oral mouth rinse (twice a day; 3M ESPE, Maplewood, Minn). Over-the-counter pain medications were recommended (including ibuprofen and acetaminophen), and oral hygiene instructions were given. At the 4-month postoperative follow-up appointment, the patient demonstrated proper healing with no pain or complications. The patient's prosthetic workup was completed, and a screw-retained crown was successfully placed with no complications.

Case 2

A 53-year-old woman presented to the SD clinic with a chief complaint of pressure sensitivity in the left area of her mandible when chewing tough foods like steak and bagels. Tooth #19 was tested and determined to be vital, with no thermal sensitivity, but large recurrent decay was noted on the periapical radiograph and clinically under the buccal margin of an existing crown (Figure 3).

The patient's medical history included treatment for high blood pressure, asthma, seasonal allergies, frequent headaches, sinus problems, and hypothyroidism. Her current medications included Armour Thyroid, lisinopril, montelukast, fluticasone, loratadine with psuedoephedrine, albuterol, formoterol, rizatriptan, naproxen, esomeprazole, lamotrigine, vitamin D, trazodone, and benzonatate. She had an unremarkable past surgical history. The patient denied smoking or recreational drug use but admitted to social alcohol use.

Treatment options and their benefits and risks were discussed with the patient. These included crown lengthening, root canal therapy, post buildup and new crown, or tooth extraction followed by placement of a removable partial denture, three-unit fixed bridge, or dental implant. The patient chose to have the tooth extracted and an implant placed.

A 3-D CBCT scan and optical surface scan were taken. These data were aligned using SIMPLANT 17 implant planning software. The teeth were segmented from the CBCT data as a separate optical surface layer. In a software simulation, an ideally sized implant was virtually placed, in keeping with well-known design guidelines like Tarnow's rule and the 3a2b rule.[1–3] To assist in visualizing the 5-TG placement, the bone volume was turned off and the layer with the surface rendering of the teeth was turned on. The teeth were rendered in a gold color, with the implant colored green. The implant was virtually viewed from a variety of angles to confirm that five full threads engaged the bone or that bi-socket or tri-socket stabilization existed. The virtual rendering created clearly shows five full threads apical to the socket as well as the entire buccal and lingual surfaces of the implant contacting bone (Figure 4). With five full threads plus bi-socket engagement confirmed, the likelihood of primary stability was considered good, per 5-TG criteria.

The virtual plan was completed, and an order was placed for a fully guided, tooth-supported surgical guide. The patient was informed of a good probability of extraction followed by immediate placement, and a surgery date was set. The finalized and agreed-upon treatment plan called for atraumatic extraction of tooth #19, immediate implant placement, and bone grafting of any gaps between the implant and socket walls. No provisionalization was necessary, since the surgical site was not noticeable in the patient's smile.

The dental team reviewed and agreed upon the patient's treatment plan before beginning the procedure. The patient's vital signs were within normal limits. A topical anesthetic was placed, and an inferior alveolar nerve block was administered using 2% lidocaine with 1:100 000 epinephrine. The soft tissue was elevated with a #9 molt periosteal elevator, and the tooth was avulsed using #23 extraction forceps in a pumping motion. The socket was curetted and irrigated with copious amounts of normal saline solution. The tooth-borne surgical guide was evaluated for proper fit. A normal osteotomy drilling sequence was performed, and the implant was placed through the guide to a specified drill stop with the aid of a slow-speed hand piece.

The implant demonstrated good primary stability with no mobility. A stock healing cap was placed. Mineralized cortical and cancellous bone chips were hydrated in normal saline solution and packed into all gaps between the implant and socket walls. The graft was secured with high-viscosity PeriAcryl and covered with petroleum jelly to prevent unplanned attachment to the surrounding tissues. No hemostasis aids were needed.

Postoperatively, the patient was told to use antibiotics (amoxicillin 500 mg three times a day for five days) and Peridex chlorhexidine gluconate 0.12% oral mouth rinse (twice a day). Over-the-counter pain medications were recommended (including ibuprofen and acetaminophen), and oral hygiene instructions were provided. Four-and-a-half months after surgery at the first follow-up appointment, soft tissue that had grown over the healing cap was removed to expose the healed implant and implant stability quotient (ISQ) measurements were taken, with the average ISQ value measured as 76 (a value over 60 is preferred).[4–6] The patient's prosthetic workup was completed, and a screw-retained crown was successfully placed with no complications.

Case 3

A 56-year-old woman presented to the SD clinic with a chief complaint of chronic periodontal pain and bleeding in the maxillary left region. Screening revealed no other health problems; she had an unremarkable medical history, was currently taking no medications, and denied smoking, drinking, and recreational drug use.

Teeth #14 and #15 were previously treated via root canal therapy, buildups, post, and crowns. Tooth #14 demonstrated bleeding on probing. Furcal involvement was evaluated as Grade II. Large radicular decay was noted on the periapical radiograph (Figure 5) and via clinical observation. Tooth #15 had moderate bone loss on the distal side, with no opposing tooth.

The options, benefits, and risks were presented to the patient, which included no treatment or extracting tooth #14 followed by placement of a removable partial denture, three-unit fixed bridge, or dental implant. The patient elected to have tooth #14 extracted and an implant placed. The patient also chose to have tooth #15 extracted, due to its lack of masticatory function and possible future complications.

A 3-D CBCT scan and optical surface scan were taken. These data were aligned using Sidexis XG 2.63 software (Dentsply Sirona). The CBCT data were adjusted to reveal the teeth without the surrounding bone. In a software simulation, an ideally sized implant was virtually placed, in keeping with well-known design guidelines like Tarnow's rule and the 3a2b rule.[1–3] The implant was virtually viewed from a variety of angles to confirm that five full threads engaged the bone or if bi-socket or tri-socket stabilization existed. The virtual rendering produced clearly shows five full threads apical to the sockets (Figure 6), which indicated that the likelihood of primary stability is good, according to 5-TG principles.

The virtual plan was finalized, and an order was placed for a fully guided, tooth-supported surgical guide. The patient was informed of a good probability of extraction and immediate placement, and the surgery date was scheduled. The finalized and approved treatment plan involved atraumatic extraction of teeth #14 and #15, immediate implant placement in the #14 socket, and bone grafting of any gaps between the implant and socket walls. No provisionalization was necessary, since the surgical site would not be visible while the patient smiled.

The patient's treatment plan was reviewed and agreed upon by the dental team prior to beginning the procedure. The patient's vital signs were within normal limits. A topical anesthetic was placed, and a posterior superior alveolar nerve block was administered, using 4% articaine hydrochloride with 1:100 000 epinephrine. The soft tissue was elevated with a #9 molt periosteal elevator, and the teeth were avulsed using a #88L extracting forceps. All radicular bone remained intact. The socket was curetted and irrigated with ample amounts of normal saline solution. The tooth-borne surgical guide was evaluated for proper fit. The normal osteotomy drilling sequence was performed, and the implant was placed through the guide to a specified drill stop using a slow-speed hand piece. The implant demonstrated good primary stability with no mobility. Next, a normal healing cap was placed. Mineralized cortical and cancellous bone chips were hydrated in normal saline solution and packed into all gaps between the implant and socket walls as well as the #15 socket site. The graft was secured with high-viscosity PeriAcryl and topped with petroleum jelly to prevent unwanted attachment to the surrounding tissues. No hemostasis aids were needed.

After the procedure, the patient was instructed to use Peridex chlorhexidine gluconate 0.12% oral mouth rinse (twice a day) and antibiotics (amoxicillin 500 mg three times a day for five days). Over-the-counter pain medications were recommended (including ibuprofen and acetaminophen), and oral hygiene instructions were given. At the 4-month follow-up appointment, soft tissue that had grown over the healing cap was removed to expose the healed implant and ISQ measurements were taken, with the average ISQ value noted as 75. The patient's prosthetic workup was completed, and a screw-retained crown was successfully placed with no complications.

Discussion

The 5-TG recommends engaging a minimum of five implant cylinder threads in the native bone in order to better ensure primary stability. This concept comes from well-founded engineering principles. Studies have shown that the distribution of forces along the length of a nut is not uniform, due to the strains set up in the bolt and nut under load under these conditions. Approximately 93% of the load is distributed over the first five threads (Figure 7).[7–10] Aware of these findings, design engineers typically manufacture commercially available nuts with five threads. Using fewer than five threads could result in failure and providing more than five threads does not offer any significant advantage.[11–16]

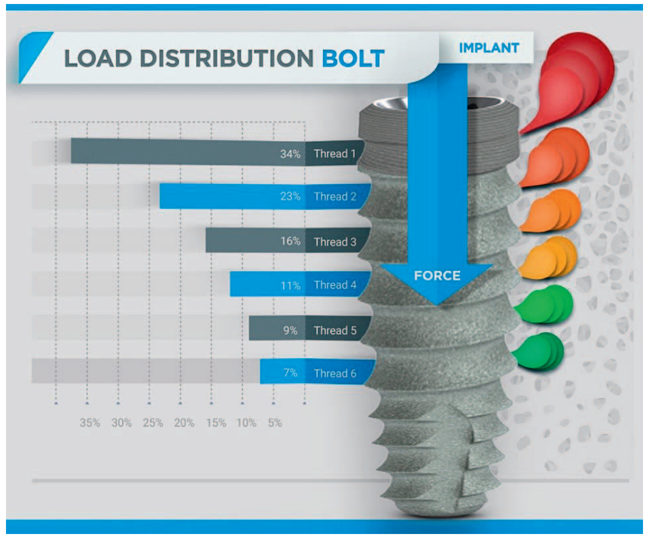


Figure 7. Graphic illustration of the typical nut-to-bolt stress distribution (left of the implant) compared to crestal stress distributions typically found on dental implants (right of the implant).

In structural design, the material property of the nut is often times selected to be similar, if not identical, to that of the bolt to prevent stripping of the threads. The main material property of concern is the modulus of elasticity (MOE). For the sake of simplicity, think of MOE as the stiffness of the material. In other words, the bolt and nut should be made of similar material to prevent the nut or the bolt from undergoing plastic deformation (thread stripping).

This concept is referred to as modulus matching,[16] a proper understanding of which is paramount to properly implement the 5-TG. The Misch bone density classification system (D1–D4) provides clinicians the opportunity to assess when modulus matching, or mismatching, occurs. The MOE of titanium alloys is most similar to dense bone (D1) and least like soft bone (D4).[17] For example, if one were to place an implant into D1 bone the 5-TG would indicate a high likelihood of primary stability, since the titanium dental implant and D1 bone are elastically similar. When placing into D2 or D3 bone, the likelihood of primary stability would be considered moderate. Due to the larger modulus mismatch between soft D4 bone, like woven bone of repair, and titanium implants, the crestal stress might exceed the bone's ability to tolerate the strain and result in pathological overload. Armed with the 5-TG a prudent clinical approach would be to strive for more than five threads to decrease risk of implant failure or allow the bone to mature prior to implant placement.

Through finite element analysis and photoelastic experi-

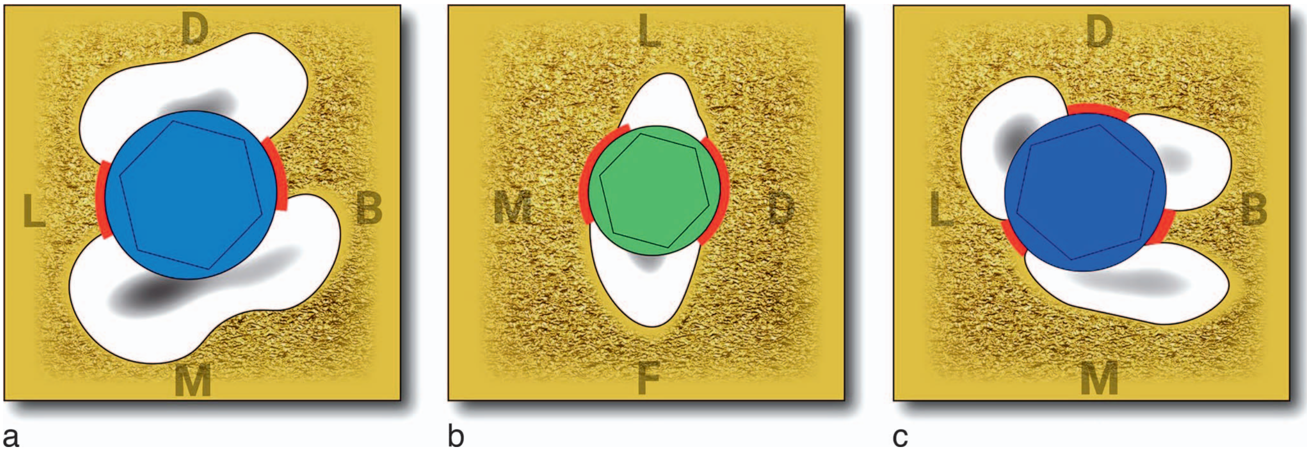


Figure 8. (a) A two-rooted tooth, like a mandibular first molar, provides bi-socket stabilization. (b) A single-rooted tooth, like a mandibular incisor, typically provides bi-socket stabilization. (c) A three-rooted tooth, like a maxillary first molar, provides tri-socket stabilization (red lines indicate areas of bone-to-implant contact).

ments, research has shown that the stress distribution within a bone-to-titanium implant relationship is concentrated in the implant's crestal region.[17–20] This finding is strikingly similar to the load distribution of a bolt and nut.[6] Thus, the 5-TG can be extrapolated as a tool to predict primary implant stability.

Currently, there are hundreds of different dental implant manufacturers; however, many implant designs are beginning to converge on a thread pitch of approximately one thread per millimeter of implant length.[21] Therefore, if you select a 10-mm-long implant with a 1-mm thread pitch, the implant would have 10 threads from top to bottom. Hence, for the 5-TG to apply, you need five threads in the bone or the equivalent of 5 mm of native (undisturbed) bone.

The 5-TG can be utilized in healed and immediate extraction sites. It is safe to assume that if you have five threads surrounded in bone, the likelihood of primary stability is good. A supporting example would be a subantral lateral window sinus graft in a healed site. The minimum sinus floor thickness to consider a simultaneous sinus graft and implant placement is 5 mm, as reported by Misch. Using an implant with a thread pitch of one thread per millimeter and placing it into 5 mm of subantral bone equates to five complete threads engaging bone and a good prognosis for primary stability.[22]

When placing a dental implant into fresh socket sites, you do not typically encounter 5 mm of intact native bone. Instead, you will more likely encounter regions of intact bone composed of dense lamina dura, cortical bone, and soft trabecular bone as well as areas with no bone (socket). These conditions vary throughout the mouth and are site specific. Immediate placement into the radicular bone of a first molar involves different stability parameters than immediate placement into a lower lateral incisor. Fortunately, the 5-TG works for all locations and all teeth, including one-, two-, and three-rooted teeth.

In one-rooted teeth in the anterior maxilla, the floor of the nose often prevents placing an implant a full five threads apically to the socket. However, you can usually engage three full threads simultaneously with five threads on the mesial and distal of the socket walls. This five-thread bi-socket stabilization creates a clamping force that provides adequate primary stability (Figure 8b).

For teeth with two roots, like mandibular molars, the conditions are similar to a single-rooted tooth. Three full threads are typically engaged in the apical region, although this time the five-thread bi-socket stabilization comes from the buccal and lingual interradicular bone (Figure 8a).

One might assume that a three-rooted tooth would be the most challenging site for immediate implant placement. However, teeth with three roots have an advantage over single-rooted and two-rooted teeth. The interradicular bone of a three-rooted tooth creates tri-socket stabilization, resulting in good primary stability—similar to how a tripod is more stable than a bipod and monopod. With five-thread tri-socket stabilization, the probability of primary stability is high (Figure 8c).

The 5-TG can be applied to traditional two-dimensional images (periapical radiographs) or 3-D images. However, 3-D images provide superior visualization and, thus, a better prediction of implant primary stability, as noted in Figures 2, 4, and 6. Implementation requires two things: (1) a CBCT scan and (2) a computer equipped with planning software. The proposed restoration and ideal dental implant are then virtually added to the plan. Next, the model can be rotated into various positions, allowing the clinician to visualize the implant's thread-to-bone contact. Applying the 5-TG to the visual data provides the clinician an accurate prediction of implant primary stability.

Conclusions

Considering well-known nut-and-bolt mechanics as well as stress distribution studies on implants, one can infer a guideline for predicting implant stability in healed or immediate extraction sites. The concomitant use of radiographs and virtual implant planning software can better predict the likelihood of surgical placement success when using the 5-TG, which dictates that if you have a full five threads entirely engaging the bone or five threads in bi-socket or tri-socket stabilization, the likelihood of primary stability is good. The 5-TG should not be used alone, rather it should be used in conjunction with implantology's other well-established guidelines to reduce risk and improve the likelihood of implant primary stability.

Abbreviations

5-TG: five-thread guideline
CBCT: cone beam computerized tomography
ISQ: implant stability quotient
MOE: modulus of elasticity

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