Effect of Simplified One-Step Drilling Protocol on Osseointegration

Arpita Patel, DDS[1]/Luiz F. Gil, DDS, MS[2]
Arthur Castellano, DDS[1]/Gileade Freitas, DDS, MD[3]
Daniel Navarro, DDS, MS[4]/Ana P. Peredo, BS[5]
Nick Tovar, PhD[1]/Paulo Coelho, DDS, PhD[1]

This study was designed to compare the combined effect of two different drilling techniques (conventional expansion and one-step) and four different implant geometries in a beagle dog model. The nondecalcified bone-implant samples underwent histologic/metric analysis at 2 and 6 weeks. Morphologic analysis showed similarities between different drilling technique groups and implant geometries. Histomorphometric parameters, bone-to-implant contact (BIC), and bone area fraction occupancy (BAFO) were analyzed, and no statistical difference between drilling groups and/or implant geometry was found. Time was the only variable that affected BIC and BAFO, suggesting that the two protocols are equally biocompatible and osseoconductive. Int J Periodontics Restorative Dent 2016;36:e82–e87. doi: 10.11607/prd.2755

[1]Department of Biomaterials and Biomimetics, New York University, New York, New York, USA.
[2]Postgraduate Program in Dentistry, Federal University of Santa Catarina, Florianópolis, Santa Catarina, Brazil.
[3]Department of Oral and Maxillofacial Surgery, Ribeirão Preto School of Dentistry, Ribeirão Preto, São Paulo, Brazil.
[4]Department of Materials Science, Military Institute of Engineering, Rio de Janeiro, Brazil.
[5]Department of Biomedical Engineering, Rochester Institute of Technology, Rochester, New York, USA.

Correspondence to: Luiz Fernando Gil Tenente Silveira, 293, 10 andar, sala 1001 – Centro – Florianópolis/SC, Brasil 88010-301. Fax: +55 48 32234185. Email: luizfgil@hotmail.com

The success of dental implant treatment relies on the effective achievement and maintenance of osseointegration. It has been clinically suggested that reliable osseointegration is dependent on various factors, such as implant biocompatibility, design, and surface; the state of the host bed; surgical technique; and loading conditions.[1,2] Studies have suggested that surgical experience, surgical procedures, and surgical tools play a key role in treatment success.[3–7] Although they are important, many steps of the surgical technique (from incision to closure) are scientifically underestimated. For instance, drilling protocols are not strongly based in the literature but commonly dictated by implant manufacturers.

Previous studies concerning drilling protocols have shown comparable bone apposition when comparing conventional gradual drilling expansion to its simplified version (pilot drill to final drilling diameter without gradual expansion).[8–11] From a surgical standpoint, reducing the number of burs decreases the operative time, resulting in fewer postsurgical complications.[12] However, the chance to correct implant location and angulation is limited, which could impair functional and esthetic outcomes.

Osseointegration as a dynamic phenomenon depends on the interplay of different factors.

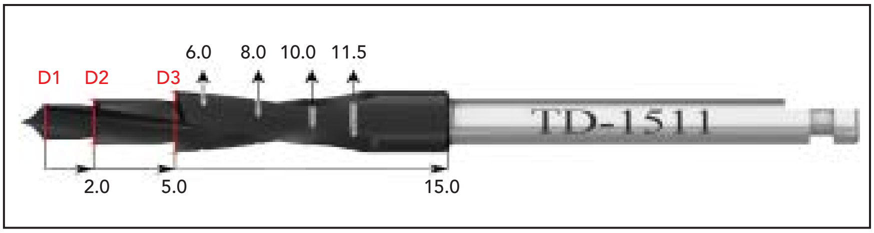

Fig 1 *Single three-step drill used in the simplified protocol; as the length of drill increases, the diameter increases.*

Thus, investigating how these factors interact in the early phases of bone healing is of great interest. For instance, different pathways of bone healing (interfacial remodeling or intramembanous-like) can result from the relation of implant macrogeometry and drilling protocols.[13,14] Optimization of the interaction between these factors could promote better early and long-term osseointegration.

Thus, the objective of the current study was to observe and compare histologically and histomorphometrically the combined effect of drilling sequences (one-step drilling versus gradual expansion) and implant macrogeometries in a beagle dog model.

Materials and methods

Implants

A total of 80 endosteal implants (ø 3.7 × 10 mm in length) were used in this study, with four macrogeometric variations (n = 20 per design), based on a commercially available implant (Standard Internal Hex, Adin). All implant groups presented the Osseofix (Adin) surface treatment.[15] The variations were as follows:

- Design 1 (D1): Implant with a small groove on the thread tip outer diameter
- Design 2 (D2): Implant with a large groove on the thread tip outer diameter
- Design C: Control
- Design W: Implant of identical geometry relative to control obtained through laser sintering

Surgical technique

Within the same macrogeometry group, half the implants were inserted using a simplified drilling procedure (three-step drill drilling group) and the other half were placed using the conventional sequence recommended by the manufacturer (conventional drilling group).

The simplified protocol was performed with a single three-step drill, the diameter of which incrementally increases as its length increases (Fig 1). The conventional drilling procedure comprised a progressive expansion of the osteotomy site with a sequence of drills (pilot drill ø1.5 mm, followed by intermediate drills of ø2.0, ø2.5, and ø3.0 mm and a final drill of ø3.5 mm). The drilling speed was 900 rpm for all techniques. Drilling was performed under abundant sterile saline irrigation.

Ten beagle dogs (each approximately 1.5 years of age) were used for the study. The study was conducted under the approval of the committee for animal experimentation at the Ecole Veterinaire D'Alfort, France (#B940462). All surgical procedures were performed with the subjects under general anesthesia, at first using an intramuscular ketamine chlorate injection (15 mg/kg) and maintained by an inhalatory protocol of isoflurane. Preoperatively, the animals received an intramuscular administration of atropine sulfate (0.044 mg/kg) to decrease parasympathetic muscle activity and xylazine chlorate (8 mg/kg) to induce anesthesia.

After incision and surgical exposure, four implants were placed in the proximal tibia and both right and left limbs received D1, D2, C, and W implants placed with simplified (right side) or conventional drilling protocol (left side). The experimental group implant sequence from proximal to distal was interpolated to minimize implantation bias due to different cortical-to-trabecular ratios between sites. After surgery, the muscle layer was sutured with a bioresorbable suture

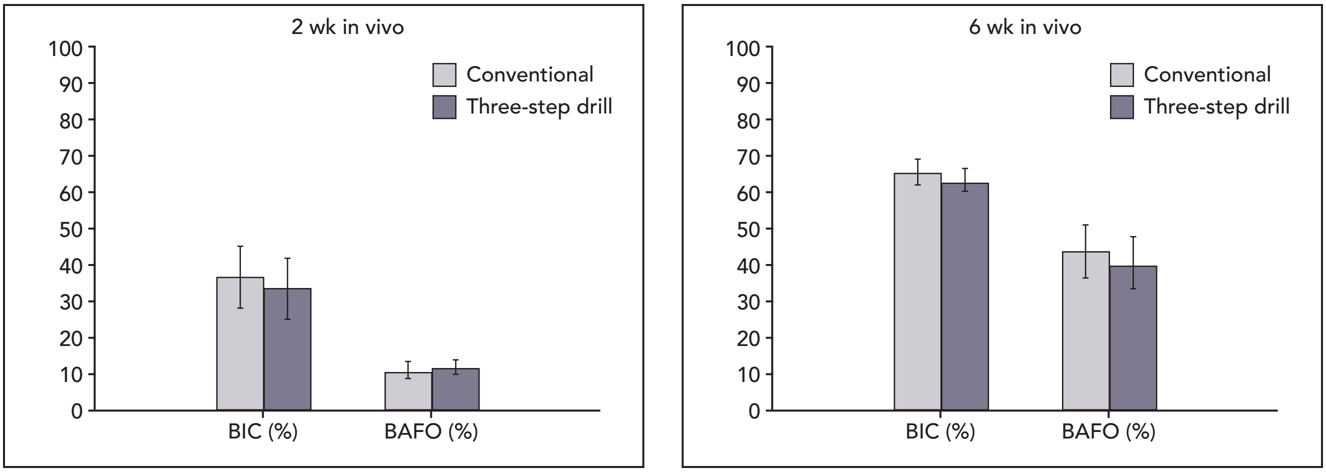

Fig 2 *Different drilling techniques at different time points for both histomorphometric analyses (BIC and BAFO).*

and the skin layer was sutured with a nylon suture. Postoperatively, antibiotics (penicillin, 20,000 UI/Kg) and analgesics (ketoprofen, 1 ml/5 kg) were administered.

After periods of 2 and 6 weeks, the animals were euthanized by an anesthesia overdose (n = 5 per time point) and the implants and surrounding bone removed en bloc and were fixed in 10% buffered formalin solution for 24 hours. After fixation, the samples underwent dehydration in a series of ethanol solutions ranging from 70% to 100%. Thereafter, they were embedded in a methacrylate-based resin (Technovit 9100, Heraeus Kulzer) according to the manufacturer's instructions. The embedded blocks were cut in the middle of the implant, and one central nondecalcified cut and ground section was prepared to a final thickness of 50 μm. The sections were then stained in Stevenel blue and van Gieson picrofuschin stain. The stained sections were scanned to digital format using a histology slide scanning system (Aperio Technologies). Histomorphometric measurements of bone-to-implant contact (BIC) and bone area fraction occupancy (BAFO) were obtained via image analyzing software (ImageJ, National Institutes of Health).[15,16]

Statistical analysis

Due to variance in homogeneity between 2 and 6 weeks in vivo, the effects of the independent variables of drilling technique and implant macrogeometry per time in vivo on the dependent variables of BIC and BAFO were evaluated using one-way analysis of variance and post hoc least significant difference tests. Statistical significance was set at 5% ($\alpha = .05$).

Results

Surgical interventions and postoperative period occurred with no complications, and all devices were clinically stable immediately after euthanasia. No signs of inflammation or infection were observed in the tissue surrounding the implanted devices.

The histomorphometric results when all variables were collapsed over implant design depicted no significant differences between experimental implant groups ($P > .70$), thus the data is presented as a function of time and surgical drilling technique in Fig 2. No statistical difference between drilling techniques could be noted for BIC and BAFO at 2 or 6 weeks. When all variables were presented, no significant effect (all $P > .56$) in BIC or BAFO of a specific implant design was detected for either technique or when comparing the same implant design under different drilling protocols (Figs 3 and 4, respectively). Histomorphometric parameters significantly increased from 2 to 6 weeks. Time was the only factor that had a significant effect on the BIC and BAFO values ($P < .001$).

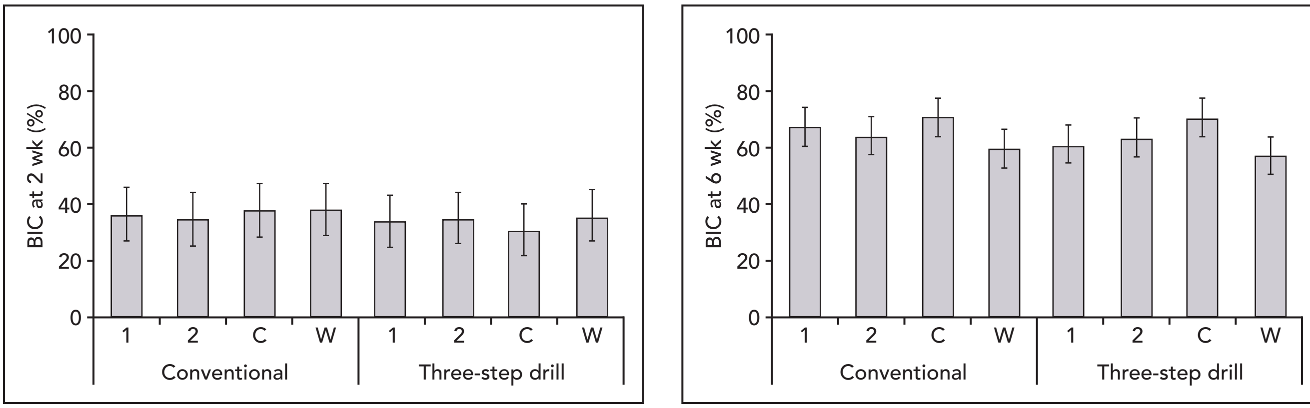

Fig 3 *Summary statistical results (mean ± SD) for BIC showing that different drilling techniques resulted in no significant difference among all four implant designs at the two time points.*

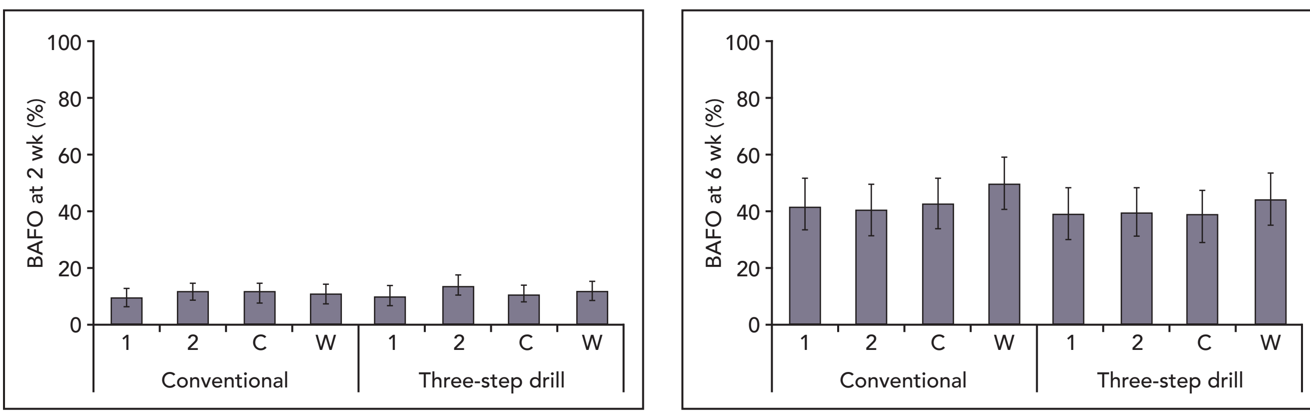

Fig 4 *Summary statistical results (mean ± SD) for BAFO showing that different drilling techniques resulted in no significant difference among all four implant designs at the two time points.*

No qualitative difference in peri-implant histology was depicted for the drilling techniques or between implant designs. Only a temporal histomorphologic difference was noted (Fig 5). At 2 weeks (Fig 5a), implants were mostly filled by woven bone at the healing chambers formed due to the mismatch between the implant inner diameter and surgical instrumentation. At 6 weeks (Fig 5b), initial signs of remodeling were seen as an appreciable onset of lamellar bone formation for most samples in the areas where initial woven bone was observed at 2 weeks.

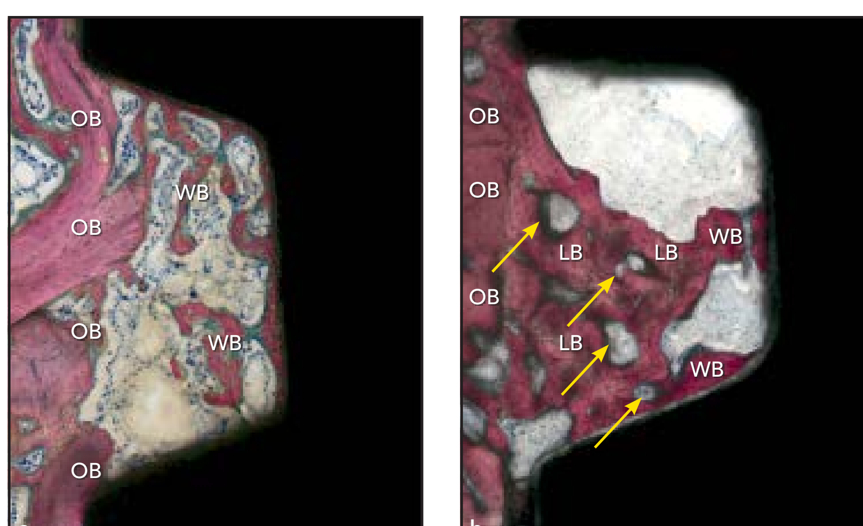

Fig 5 *Light microscopy images showing the healing chamber at* (a) *2 weeks and* (b) *6 weeks (×200 Stevenel blue and van Gieson picrofuschin stain). Arrows indicate primary osteonic structures. OB = old cortical bone; WB = woven bone; LB = lamellar bone.*

Discussion

This study investigated the combined effect of different drilling protocols and different implant macrogeometries on osseointegration. The traditional protocol of progressive osteotomy expansion was based on the expectation that it poduced less trauma during instrumentation, mainly by controlling bone overheating, which is a known factor of thermal osteonecrosis and early implant failure.[17–20] However, recent studies on this topic have shown no detrimental effect on osseointegration when the simplified drilling technique is performed, which is in agreement with the present study.[8–11] Histologic evaluation showed no signs of thermal necrosis or gross inflammation when the simplified protocol was used. In fact, qualitative analyses indicated strong similarities in bone healing between drilling techniques.

The feasibility of the simplified one-drill protocol was also confirmed by the histomorphometric analysis. No significant difference for BIC and BAFO could be detected when all implant design was collapsed over drilling technique at either time point. The potential for temperature rise with a single-step drill was minimized by irrigation during drilling, which is commonly recommended by implant manufacturers and has been found to be an efficient way to keep bone temperature below the osteonecrosis temperature threshold.[4,6,21]

Osseointegration as a multivariable process depends on numerous factors, and the interaction between implant macrogeometry and surgical instrumentation plays a key role in the phenomenon.[22] Different drilling techniques could result in differences in compression or pressure generated to bone during instrumentation and, along with different implant macrogeometries, determine distinct bone healing scenarios. The present histomorphometric results showed that no statistical differences among the macrogeometries in each technique were obtained in either time point or when comparing the same macrogeometry performance for both techniques. Thus, one can speculate that minimal difference in osteotomy dimension resulted in clinically similar bone compression levels regardless of surgical drilling technique.

When choosing among different techniques, the main deciding factor should be the biologic outcome. Only then should factors such as operative time, cost, and efficiency be taken into account. Simplifying implant instrumentation with a multistep drill provided the same biologic outcome as the traditional protocol but overcame not only the conventional technique by reducing surgical time and potential patient cost but also the most common method of simplification by applying the pilot and the final drill of a given implant system. However, in single-drill instrumentation the practitioner has just one opportunity to properly position and angulate the implant final placement, thus professional experience becomes a factor. In such a scenario, preprosthetic planning and surgical guide construction are strongly recommended.

Conclusions

The results obtained in the current study suggest that different protocols could expand treatment modalities, since no statistical difference in BIC or BAFO was obtained when morphologic and metric histologic parameters were considered for either drilling sequence. Future studies are warranted to determine the optimal association between drilling speed and technique for different bone types and volumes as well as interplay with other implant macrogeometries.

Acknowledgments

The authors reported no conflicts of interest related to this study.

References

1. Albrektsson T, Brånemark PI, Hansson HA, Lindström J. Osseointegrated titanium implants. Requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. Acta Orthop Scand 1981;52:155–170.
2. Mavrogenis AF, Dimitriou R, Parvizi J, Babis GC. Biology of implant osseointegration. J Musculoskelet Neuronal Interact 2009;9:61–71.
3. Kim SJ, Yoo J, Kim YS, Shin SW. Temperature change in pig rib bone during implant site preparation by low-speed drilling. J Appl Oral Sci 2010;18:522–527.
4. Augustin G, Davila S, Mihoci K, Udiljak T, Vedrina DS, Antabak A. Thermal osteonecrosis and bone drilling parameters revisited. Arch Orthop Trauma Surg 2008;128:71–77.
5. Lambert PM, Morris HF, Ochi S. Positive effect of surgical experience with implants on second-stage implant survival. J Oral Maxillofac Surg 1997;55:12–18.

6. Sener BC, Dergin G, Gursoy B, Kelesoglu E, Slih I. Effects of irrigation temperature on heat control in vitro at different drilling depths. Clin Oral Implants Res 2009;20:294–298.
7. Yeniyol S, Jimbo R, Marin C, Tovar N, Janal MN, Coelho PG. The effect of drilling speed on early bone healing to oral implants. Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116:550–555.
8. Giro G, Tovar N, Marin C, et al. The effect of simplifying dental implant drilling sequence on osseointegration: An experimental study in dogs. Int J Biomater 2013;2013:230310.
9. Jimbo R, Giro G, Marin C, et al. Simplified drilling technique does not decrease dental implant osseointegration: A preliminary report. J Periodontol 2013; 84:1599–1605.
10. 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.
11. Sarendranath A, Khan R, Tovar N, et al. Effect of low speed drilling on osseointegration using simplified drilling procedures. Br J Oral Maxillofac Surg 2015; 53:550–556.
12. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR. Guideline for Prevention of Surgical Site Infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. Am J Infect Control 1999;27:97–132.
13. Coelho PG, Suzuki M, Guimaraes MV, et al. Early bone healing around different implant bulk designs and surgical techniques: A study in dogs. Clin Implant Dent Relat Res 2010;12:202–208.
14. Leonard G, Coelho P, Polyzois I, Stassen L, Claffey N. A study of the bone healing kinetics of plateau versus screw root design titanium dental implants. Clin Oral Implants Res 2009;20:232–239.
15. Coelho PG, Marin C, Granato R, Giro G, Suzuki M, Bonfante EA. Biomechanical and histologic evaluation of non-washed resorbable blasting media and alumina-blasted/acid-etched surfaces. Clin Oral Implants Res 2012;23:132–135.
16. Witek L, Marin C, Granato R, et al. Characterization and in vivo evaluation of laser sintered dental endosseous implants in dogs. J Biomed Mater Res B Appl Biomater 2012;100:1566–1573.
17. Eriksson A, Albrektsson T, Grane B, McQueen D. Thermal injury to bone. A vital-microscopic description of heat effects. Int J Oral Surg 1982;11:115–121.
18. Eriksson AR, Albrektsson T, Albrektsson B. Heat caused by drilling cortical bone. Temperature measured in vivo in patients and animals. Acta Orthop Scand 1984;55:629–631.
19. Augustin G, Davila S, Udilljak T, Staroveski T, Brezak D, Babic S. Temperature changes during cortical bone drilling with a newly designed step drill and an internally cooled drill. Int Orthop 2012; 36:1449–1456.
20. Reiser GM, Nevins M. The implant periapical lesion: Etiology, prevention, and treatment. Compend Contin Educ Dent 1995;16:768, 770.
21. Benington IC, Biagioni PA, Briggs J, Sheridan S, Lamey PJ. Thermal changes observed at implant sites during internal and external irrigation. Clin Oral Implants Res 2002;13:293–297.
22. Coelho PG, Jimbo R. Osseointegration of metallic devices: Current trends based on implant hardware design. Arch Biochem Biophys 2014;561:99–108.