Effects of Implant Morphology on Rotational Stability During Immediate Implant Placement in the Esthetic Zone

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Purpose: *Primary implant stability is critical to achieving implant success, especially in a situation with immediate implant placement and provisionalization (IIPP) when bone quality and quantity are compromised. The purpose of this study was to examine the effects of implant morphology (tapered vs cylindric) and the final drill–implant diameter discrepancy (FD–IDD) of six implant systems on the incidence of rotational instability during IIPP in the esthetic zone.* ***Materials and Methods:*** *One hundred seventy-one implants in 112 patients were evaluated. Implants that exhibited inadequate resistance to the torque generated by the surgeon's hand during implant placement were classified as rotationally unstable.* ***Results:*** *The overall incidence of rotational instability for the tapered implants (1.1%) was significantly lower than that exhibited by the cylindric (nontapered) implants (20.5%). Among the cylindric implants, those with < 0.5 mm FD–IDD experienced a significantly higher incidence of rotational instability (36.6%) than groups with ≥ 0.5 mm FD–IDD. The incidence of rotational instability of cylindric implants with ≥ 0.5 mm FD–IDD was significantly greater than that of the tapered implants with a comparable FD–IDD.* ***Conclusion:*** *Within the confines of this study, the use of a tapered implant with an FD–IDD of ≥ 0.5 mm minimized the incidence of rotational implant instability for the IIPP procedure.* Int J Oral Maxillofac Implants 2015;30:667–670. doi: 10.11607/jomi.3885

Key words: *dental implants, immediate implants, immediate provisionalization, implant morphology, implant shape, implant stability*

Primary implant stability has been suggested to be a key prognostic factor for osseointegration.[1–3] However, osseointegration has also been observed in implants lacking initial stability, provided that healing was allowed without external interference.[4] Recently, the concept of tissue preservation utilizing immediate implant placement and provisionalization (IIPP) in the anterior maxilla has been advocated.[5–8] With immediate implant placement (IIP) procedures, primary implant stability is more difficult to achieve because bone availability in a fresh extraction socket is limited. Furthermore, the decision to proceed with immediate provisionalization critically depends on the level of primary implant stability achieved after IIP, as implant micromotion in the presence of a provisional restoration is inevitable. A study has shown that IIPP can be successful even when the implant insertion torque is as low as 10 Ncm, as long as the provisional restoration is bonded to the adjacent dentition.[9] On the other hand, increased insertion torque has been associated with higher implant survival rates and fewer complications.[10]

In addition to bone quality, quantity, and surgical experience, the morphology (shape) of the implant can also potentially affect implant stability in IIPP procedures. Implants with a tapered morphology have been shown to achieve more consistent primary stability than implants with a nontapered (cylindric) morphology.[11,12]

The purpose of this clinical study was to examine the effects of implant morphology and the final drill–implant diameter discrepancy (FD–IDD) of six implant systems on the incidence of rotational stability during IIPP procedures in the esthetic zone.

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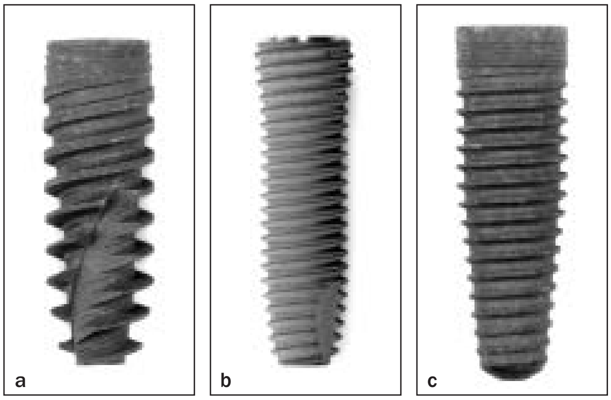
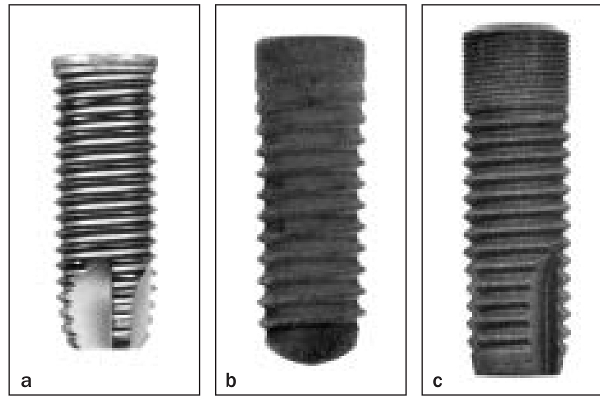
MATERIALS AND METHODS

Patient Selection

This retrospective study was approved by the institutional review board of Loma Linda University and was conducted at the Center for Prosthodontics and



Figs 1a to 1c Tapered implants. *(a)* NobelActive (self-tapping), *(b)* Dentium SuperLine, *(c)* NobelReplace.



Figs 2a to 2c Cylindric (nontapered) implants. *(a)* 3i Prevail (self-tapping tapered apex), *(b)* Straumann Bone Level (bullet-shaped apex), *(c)* Astra Tech OsseoSpeed (self-tapping square apex).

Fig 3 Example of the final drill–implant diameter discrepancy (FD–IDD).

Implant Dentistry. The treatment records of patients who underwent IIPP between May 2007 and December 2013 were reviewed. To be included in this study, the patient must have received IIPP to replace a failing anterior maxillary tooth (incisor, canine, or first premolar) with one of six commercially available implant systems. Of the six implants evaluated, three have a tapered morphology (NobelReplace Tapered, Nobel Biocare; NobelActive, Nobel Biocare; SuperLine, DentiumUSA) (Fig 1), and the other three have a nontapered (cylindric) morphology (Prevail, Biomet 3i; OsseoSpeed, Astra Tech; Bone Level SLActive, Straumann) (Fig 2). The surgical approach used for each study subject was described previously.[6,8]

Data Collection

The implant dimensions and positions were determined with the aid of study casts, periapical radiographs, and a computed tomographic scan (iCAT, Imaging Sciences International) prior to implant surgery. Following removal of the failing tooth, the implant osteotomy was developed according to the respective manufacturers' recommended drilling protocol. The implant was inserted and torqued (manufacturers' recommendation) using a surgical motor until the platform reached the desired depth in relationship to the predetermined facial gingival margin.[6,8] If the insertion torque of the implant was less than 15 Ncm, an implant mount was attached to the implant, and the rotational stability of the implant was then evaluated manually (by hand) via attempts to rotate the mount gently both clockwise and counterclockwise. Implants that exhibited inadequate resistance to the torque generated by the surgeon's hand (spinning) were classified as rotationally unstable.

The diameters of the final drills and the corresponding implants at various levels (manufacturer specifications) (Fig 3) were obtained from the respective manufacturers, and their corresponding FD–IDD were calculated.

Statistical Analysis

Descriptive statistics were used to report the incidence of rotational instability within each implant system. The Fisher exact test was used to compare the incidence of rotational instability between the tapered and cylindric groups and between implants with different FD–IDD. The level of significance was set at $\alpha = .05$.

RESULTS

A total of 112 patients (54 men and 58 women) with a mean age of 51.7 years (range, 26 to 87 years) were included in this study. Six implant systems with different morphology (Figs 1 and 2) were used for immediate

Table 1 Incidence of Rotational Instability According to Implant Morphology and FD–IDD

Implant type/brand	FD–IDD (mm)	Rotational instability	Cylindric, FD–IDD, 0.5 mm vs ≥ 0.5 mm	FD–IDD ≥ 0.5 mm, tapered vs cylindric	Overall, tapered vs cylindric
Tapered					
NA	0.70–1.10	0/37 (0%)	N/A		
SL	0.65–0.75	1/21 (4.8%)	N/A	1/93 (1.1%)	1/93 (1.1%)
NR	0.54–0.72	0/35 (0%)	N/A		
Cylindric					
PV	0.50–1.15	2/20 (10%)	5/48 (10.4%)	5/48 (10.4%)	
BL	0.60	3/28 (10.7%)			16/78 (20.5%)
OS	0.30	11/30 (36.6%)	11/30 (36.6%)	N/A	
P value			.009*	.018*	< .001*

NA = NobelActive; SL = Dentium SuperLine; NR = NobelReplace Tapered; PV = 3i Prevail; BL = Straumann Bone Level; OS = Astra Tech OsseoSpeed. Narrow, regular, and wide platforms were all included.
* Statistically significant difference (Fisher exact test, $\alpha \leq .05$).

tooth replacement in the maxillary arch. A total of 171 implants were placed in the following locations: 86 central incisors, 53 lateral incisors, 18 canines, and 14 first premolars.

Table 1 compares the incidence of rotational instability according to implant morphology and FD–IDD. The overall incidence of rotational instability of the tapered implants (1.1%) was significantly lower than that exhibited by the cylindric implants (20.5%) (Table 1; $P < .001$). Among the nontapered implants, the group with < 0.5 mm FD–IDD (OsseoSpeed; 0.3 mm) experienced a significantly higher incidence of rotational instability (36.6%) than the group with ≥ 0.5 mm FD–IDD (Prevail, 10%; Bone Level, 10.7%) (Table 1; $P = .009$). The incidence of rotational instability in cylindric implants with ≥ 0.5 mm FD–IDD was significantly greater than that of the tapered implants with comparable FD–IDD (Table 1; $P = .018$).

The unstable implants (1 tapered and 16 nontapered) were removed and replaced with wider and/or longer implants of the same system. Consequently, adequate primary stability was achieved for all implants, and immediate provisionalization was successfully performed.

DISCUSSION

Primary implant stability has been found to be directly related to the morphology of an implant.[11–19] In this study, controlled hand torque was used to evaluate rotational implant stability. Dellinges and Tebrock reported that the maximum torque generated to handheld prosthetic screwdrivers was approximately 12 Ncm.[20] In this study, the overall incidence of rotational instability of the tapered implants (1.1%) was significantly lower than that exhibited by the cylindric implants (20.5%; Table 1) ($P < .001$). This may be a result of the fact that, in contrast to cylindric implants, tapered implants allow compressive forces to be distributed to the surrounding bone as they are inserted.[11–19] This contributes to the compaction of bone at the osteotomy site, resulting in increased insertion torque and implant stability.[11–19] With limited bone available after extraction, the smaller apical portion of the tapered implants also facilitates better and/or more bone engagement with immediately placed implants. Furthermore, the stability of tapered implants can easily be increased by a minor change in the depth of implant placement. The wider coronal portion of the tapered implant will continue to engage the narrower osteotomy site as the implant is inserted deeper, thereby improving bone engagement and implant stability. These results demonstrate that, with standard drilling protocols, it is more difficult to achieve rotational implant stability with cylindric implants during IIP.

In addition to implant morphology, the FD–IDD can also contribute to implant stability. Although the diameter of the final osteotomy drill is always smaller than the diameter of the implant, the discrepancy in size differs with each implant manufacturer (Table 1). This difference may have an impact on the amount of torque that is required to achieve primary stability. The results of this study show that, among the cylindric implants, those with < 0.5 mm FD–IDD (OsseoSpeed: 0.3 mm) experienced a noticeably higher incidence of rotational instability (36.6%) than implants with ≥ 0.5 mm FD–IDD (Prevail: 10%; Bone Level: 10.7%; Table 1, $P = .009$). Underpreparation of the osteotomy has been proposed to increase primary implant stability in situations where poor bone quality is expected.[21–27] In 2009, Lee et al described a modified drilling sequence for a nontapered implant (OsseoSpeed, Astra Tech) in immediate extraction sites.[21] These authors stated that increased primary stability could be achieved if the final drill is used only for the coronal two-thirds of the implant length.[21] The aforementioned modified methods basically improved the primary stability by increasing the FD–IDD. The fact that primary stability was achieved after the unstable implants were replaced with wider and/or longer implants in this study also substantiates the effect of FD–IDD on primary implant stability. Regardless, it is worthwhile to note that tapered implants experienced less rotational instability than the cylindric implants with comparable FD–IDD (Table 1). Surgeons with limited experience may benefit from using tapered implants and/or implants with a greater FD–IDD.

CONCLUSIONS

The achievement of primary implant stability during immediate implant placement and provisionalization in the esthetic zone can be technique-sensitive for clinicians, as bone quality and quantity are inherently compromised in comparison with implant placement in a healed site. Within the confines of this study, it was shown that the use of a tapered implant with a final drill–implant diameter discrepancy $\geq$ 0.5 mm can minimize the incidence of rotational implant instability during immediate implant placement and provisionalization.

ACKNOWLEDGMENTS

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

REFERENCES

1. Adell R, Lekholm U, Brånemark PI. Surgical procedures. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses. Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:211–232.
2. Pillar RM, Lee JM, Maniatopoulos C. Observations on the effect of movement on bone ingrowth into porous-surfaced implants. Clin Orthop Relat Res 1986;208:108–113.
3. Brunski JB. Biomaterials and biomechanics in dental implant design. Int J Oral Maxillofac Implants 1988;3:85–97.
4. Ivanoff CJ, Sennerby L, Lekholm U. Influence of initial implant mobility on the integration of titanium implants. An experimental study in rabbits. Clin Oral Implants Res 1996;7:120–127.
5. Wohrle PS. Single-tooth replacement in the aesthetic zone with immediate provisionalization: Fourteen consecutive case reports. Pract Periodontics Aesthet Dent 1998;10:1107–1114.
6. Kan JY, Rungcharassaeng K, Lozada J. Immediate placement and provisionalization of maxillary anterior single implants: 1-year prospective study. Int J Oral Maxillofac Implants 2003;18:31–39.
7. Garber DA, Salama MA, Salama H. Immediate total tooth replacement. Compend Contin Educ Dent 2001;22:210–216.
8. Kan JY, Rungcharassaeng K. Immediate placement and provisionalization of maxillary anterior single implants: A surgical and prosthodontic rationale. Pract Periodontics Aesthet Dent 2000;12:817–824.
9. Norton MR. The influence of insertion torque on the survival of immediately placed and restored single-tooth implants. Int J Oral Maxillofac Implants 2011;26:1333–1343.
10. Ottoni JM, Oliveira ZF, Mansini R, Cabral AM. Correlation between placement torque and survival of single-tooth implants. Int J Oral Maxillofac Implants 2005;20:769–776.
11. O'Sullivan D, Sennerby L, Meredith N. Measurements comparing the initial stability of five designs of dental implants: A human cadaver study. Clin Implant Dent Relat Res 2000;2:85–92.
12. O'Sullivan D, Sennerby L, Meredith N. Influence of implant taper on the primary and secondary stability of osseointegrated titanium implants. Clin Oral Implants Res 2004;15:474–480.
13. O'Sullivan D, Sennerby L, Jagger D, Meredith N. A comparison of two methods of enhancing implant primary stability. Clin Implant Dent Relat Res 2004;6:48–57.
14. Glauser R, Sennerby L, Meredith N, et al. Resonance frequency analysis of implants subjected to immediate or early functional occlusal loading. Successful vs failing implants. Clin Oral Implants Res 2004;15:428–434.
15. Glauser R, Portmann M, Ruhstaller P, Gottlow J, Scharer P. Initial implant stability using different implant designs and surgical techniques. A comparative clinical study using insertion torque and resonance frequency analysis. Appl Osseointegration Res 2001;2:6–8.
16. Meredith N. A review of implant design, geometry and placement. Appl Osseointegration Res 2008;6:6–12.
17. Lachmann S, Lavel JY, Axmann D, Weber H. Influence of implant geometry on primary insertion stability and simulated peri-implant bone loss: An in vitro study using resonance frequency analysis and damping capacity assessment. Int J Oral Maxillofac Implants 2011;26:347–355.
18. Chong L, Khocht A, Suzuki JB, Gaughan J. Effect of implant design on initial stability of tapered implants. J Oral Implantol 2009;35:130–135.
19. Martinez H, Davarpanah M, Missika P, Celletti R, Lazzara R. Optimal implant stabilization in low density bone. Clin Oral Implants Res 2001;12:423–432.
20. Dellinges MA, Tebrock OC. A measurement of torque values obtained with hand-held drivers in a simulated clinical setting. J Prosthodont 1993;2:212–214.
21. Lee EA, Su H, González-Martin O. Modified drilling sequence for immediate loading of non-conical single implants placed in extraction sockets. Pract Proced Aesthet Dent 2009;21:207–214.
22. Wong M, Eulenberger J, Schenk R, Hunziker E. Effect of surface topography on the osseointegration of implant materials in trabecular bone. J Biomed Meter Res 1995;29:1567–1575.
23. Li J. Bone-implant interface and remaining tissues on the implant surface after push-out test: An SEM observation. Biomed Mater Eng 1997;7:379–385.
24. Sakoh J, Wahlmann U, Stender E, Nat R, Al-Nawas B, Wagner W. Primary stability of a conical implant and a hybrid, cylindric screw-type implant in vitro. Int J Oral Maxillofac Implants 2006;21:560–566.
25. Ahn SJ, Leesungbok R, Lee SW, Heo YK, Kang KL. Differences in implant stability associated with various methods of preparation of the implant bed: An in vitro study. J Prosthet Dent 2012;107:366–372.
26. Fanuscu MI, Chang T-L, Akca K. Effect of surgical techniques on primary implant stability and peri-implant bone. J Oral Maxillofac Surg 2007;65:2487–2491.
27. Algbamdi H, Anand PS, Anil S. Undersized implant site preparation to enhance primary implant stability in poor bone density: A prospective clinical study. J Oral Maxillofac Surg 2011;69:e506–e512.