Comparison of Ridge Expansion and Ridge Splitting Techniques for Narrow Alveolar Ridge in a Swine Cadaver Model

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Ridge splitting and ridge expansion have been used to expand narrow alveolar ridges. Piezosurgical ridge splitting involves separating the atrophic crests with piezosurgical inserts. Ridge expansion with motor-driven expanders was proposed to achieve the cortical dilation. The purpose of this study was to evaluate the efficacy of ridge gain by ridge expansion or ridge splitting. Eighteen (36 ramus) swine cadaver jaws were first divided into two groups—ridge expansion with a motor-driven expander or ridge splitting with the piezosurgical system. Then, either an active-tapping implant or nonactive-tapping cylinder-type implant was inserted. The crestal ridge diameter change was measured with a Boley gauge. The area of bony perforation, which includes fenestrations and dehiscences, was measured with a prefabricated reference grid. The results showed that there was no statistically significant difference in crestal width gain between groups. However, the combination of the motor-driven ridge expansion technique and the active-tapping implant could be beneficial in significantly decreasing the bony perforation area. (Int J Periodontics Restorative Dent 2015;35:e44–e49. doi: 10.11607/prd.2269)

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The success of implant surgical procedures and the stability of the implant in function are related to the quality and quantity of osseous tissue. A minimum of 1.0 to 1.5 mm of surrounding bone thickness is necessary to ensure a proper mechanical and esthetic outcome.[1,2] The success and survival rates of dental implants have reached an optimum in the appropriate alveolar ridge condition. When the alveolar ridge lacks the bone volume needed to host implants, additional bone augmentation procedures often are needed to reconstruct the deficiency. A variety of ridge augmentation procedures, such as guided bone regeneration, distraction osteogenesis, onlay grafting, and interpositional inlay grafting, have been utilized to restore bone volume.[3,4] These ridge augmentation procedures are relatively aggressive and technically sensitive procedures. The alveolar ridge splitting/expansion technique is proposed to create "self-space–making defects" within the bony atrophic crests.[5–8] The buccal cortical plate is repositioned laterally with a greenstick fracture to create a new implant bed by longitudinal osteotomy of the alveolar bone. For example, Summers[9] introduced a ridge expansion technique using a series of osteotomes to create localized expansion of the developing osteotomy site. Scipioni and coworkers[1,10] introduced a bone-splitting technique in conjunction with chisels to create an expansion of the narrow ridge. However, the hammering force of the osteotome often leads to unintentional displacement of the buccal plate. Ridge expansion with a motor-driven expander system is an alternative technique to the conventional hand osteotome.[11] The bone expanders are driven by an electric handpiece at speeds of 15 to 30 rpm. The bone expander technique is a less invasive procedure in which the facial wall expands after the medullary bone is compressed against the cortical wall.[12] The bone expander technique achieves a controlled and standardized horizontal dilation of the bone.[13]

Applying piezosurgical technology to ridge-splitting procedures can provide more precise cutting and appears to cause less trauma to the hard tissue.[14,15] The Piezosurgery system works in the frequency of 25 to 29 kHz. This frequency, which creates microvibrations ranging from 60 to 210 μm in amplitude and provides the handpiece with power exceeding 5 W, cuts only mineralized tissue, whereas soft tissue such as nerves and arteries are cut at frequencies higher than 50 kHz.[16,17]

Ridge-splitting/expansion techniques can reduce surgical complexity and allow for implant placement in the narrow alveolar ridge.[18–21] Several articles have shown the implant success rate at ridge-splitting/expansion sites to be similar to that of native bone sites.[1,19,22,23]

The purpose of this study was to evaluate the efficacy of ridge gain by ridge expansion with a motor-driven expander or ridge splitting with the piezosurgical system.

Method and materials

All experiment personnel passed required examinations by the Institutional Animal Care and Use Committee (IACUC) prior to the project. The mandible of a swine cadaver has an edentulous ridge between the canine and the first premolar. These mandibles were hydrated with normal saline throughout the research procedures to mimic the intraoral environment. In standardized models, each ridge had a wider base than the crest, which was a favorable criterion to allow for ridge splitting and expansion. A total of 18 cadaver swine mandibles (36 ramus) were first divided into two groups. Each side of one ramus was randomly assigned to either ridge expansion with a motor-driven expander (BTI) or ridge splitting with the piezosurgical system (Mectron). Then, either an active-tapping implant (NobelActive [NA] 3.5 x 10 mm, Nobel Biocare) or a nonactive tapping cylinder-type implant (Straumann Bone Level [SB] 3.3 x 10 mm) was inserted.

Ridge-splitting/expansion procedure

A midcrestal gingival incision was performed, and a full-thickness flap was raised at the edentulous area between the canine and the first premolar of each ramus.

Fig 1 *BTI Biotechnology Expander system.*

Ridge-expansion (RE) group

Site preparation began with the use of a pilot drill at a speed of 700 to 800 rpm with irrigation. The pilot bur can provide accuracy and reduce the vibration and walking movements. The initial pilot bur was used to a depth of 10 mm, creating an osteotomy of 1.5 mm in diameter. The 1.8 mm and 1.8/2.5 mm burs were then subsequently used at 50 rpm without irrigation, followed by the no. 1 and no. 2 expander. The torque setting of the surgical motor was 15 to 20 Ncm. Once sufficient resistance was encountered, a manual expander with ratchet was utilized (Fig 1).

Ridge-splitting (RS) group

The initial bone preparation was made into the bone marrow space with a Piezosurgery insert (OT7S-4) to the estimated implant length (10 mm). This was followed by the IM2P insert into the estimated implant length (Fig 2).

Fig 2 (left) *Mectron Piezosurgery System, OT7S-4 insert.* (center) *IM2P insert.* (right) *Ridge splitting with piezosurgical technique.*

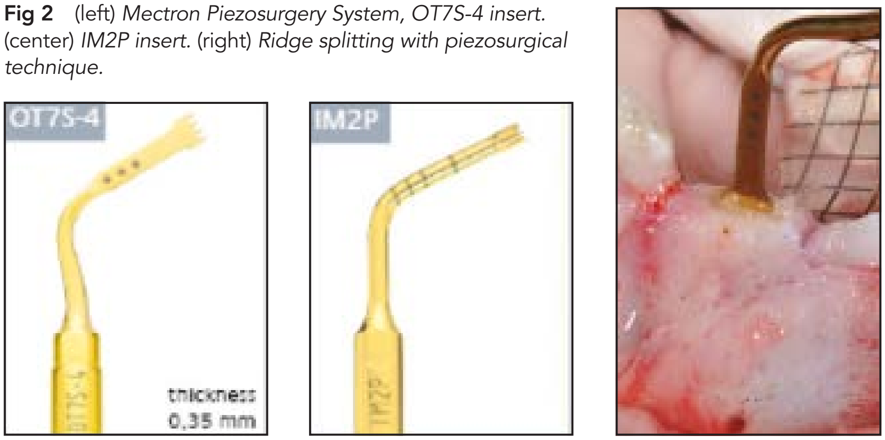

Fig 3 (left) *Straumann Bone Level implant.* (right) *Nobel Biocare Nobel-Active implant.*

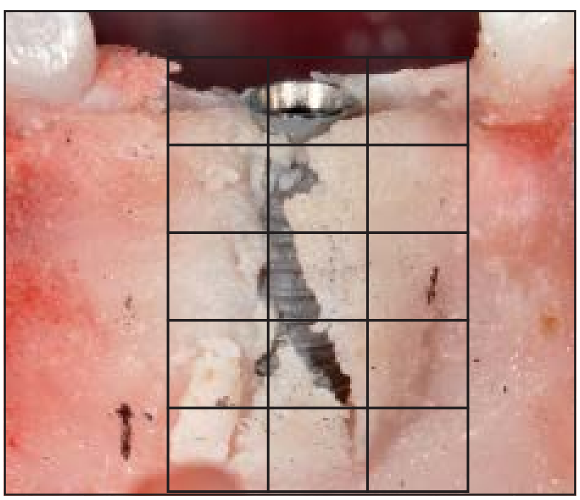

Fig 4 *The area of perforations was measured using a prefabricated grid reference ruler.*

Implant placement procedure

Based on the randomization table, the surgeon was advised to place either the active-tapping NA system or nonactive-tapping, cylinder-type SB implant. The implant placement procedure was performed according to the manufacturer's guidelines for narrow-diameter implants (Fig 3).

Active-tapping NA implant group

Traditional cylinder or straight-walled implants whose osteotomy sites have been drilled too close to the diameter of the implant tend to have decreased initial primary torque. To overcome the lack of initial resistance, self-tapping implants were designed to create compression of bone.[24] The clinical procedure was performed according to manufacturer's guidelines; the initial drill was a 2.0-mm twist drill followed by a 2.4/2.8-mm twist step drill. A narrow-diameter NA implant was then inserted into the osteotomy site.

Nonactive-tapping cylinder-type SB implant group

The implant axis was marked by drilling to a depth of 10 mm with the 2.2-mm and 2.8-mm twist drill. The SB implant was then placed at the osteotomy site.

The alveolar ridge diameter at the crestal level was measured with a Boley gauge at the following time points: baseline, after ridge expansion/splitting, and after implant placement. The area of bony perforations after ridge expansion/splitting and implant placement was measured with a prefabricated reference grid (each grid is 1 mm apart; Fig 4). Descriptive statistics were used to provide representation of the population data. A paired t test was used to evaluate whether there was a significant difference between each group. Statistical significance was declared if the P value was $\leq .05$.

Results

The mean initial crestal level alveolar ridge width was 2.88 ± 0.52 mm (RS) and 2.89 ± 0.52 mm (RE). There was no statistically significant difference of initial width ($P > .05$) between the two groups. After ridge splitting or ridge expansion, the average ridge width at the crestal level was 4.56 ± 0.61 mm (RS) and 4.81 ± 0.59 mm (RE). The average width gain at the crestal level was 1.68 ± 0.65 mm (RS) and 1.92 ± 0.61 mm (RE). The difference in crestal width gain between RS and RE groups was not statistically significant ($P > .05$; Table 1).

The total perforation area was 99.27 mm^2 and perforation rate was 27.77% in the RE group. The total perforation area was 315.65 mm^2 and perforation rate was 55.56% in the RS group. Although there was no statistically significant difference in crestal width gain between the RE and RS groups, alveolar ridges were more frequently perforated in the RS group (Table 2).

A total of 36 implants were placed; all 36 implants achieved primary stability at the surgical procedure site. In the active-tapping implant group, overall ridge width gain at the crestal level was 1.97 ± 0.66 mm and occurrence of perforation was 33.33%. In the nonactive-tapping cylinder-type implant group, overall ridge width gained at the crestal level was 1.62 ± 0.58 mm and the occurrence of perforation was 50%. Although there was no statistically significant difference ($P > .05$) in crestal width gain between two macro-design groups, there was a lower perforation rate in the active-tapping implant group (Table 3).

The initial crestal alveolar ridge width was related to the incidence of malfracture and perforation. By studying nonperforation cases after the ridge expansion/splitting procedures (defect-free cases), the overall mean initial width at the crestal level was 3.12 ± 0.39 mm (3.09 ± 0.41 mm and 3.16 ± 0.37 mm for RE and RS, respectively; Table 4).

Table 1 Initial crestal ridge width and width gain in ridge-splitting (RS) and ridge-expansion (RE) groups

	Initial crestal ridge width (mm)	Ridge width after ridge splitting/ expansion (mm)	Width gain (mm)
RS group	2.88 ± 0.52	4.56 ± 0.61	1.68 ± 0.65
RE group	2.89 ± 0.52	4.81 ± 0.59	1.92 ± 0.61
	Paired *t* test, $P = .97$*		Paired *t* test, $P = .25$**
Overall	2.89 ± 0.51	4.69 ± 0.61	1.80 ± 0.65

*No statistically significant difference of initial width ($P > .05$) between RS and RE groups.
**No statistically significant difference in crestal width gain ($P > .05$) between RS and RE groups.

Table 2 Total perforation area and perforation occurrence in ridge-splitting (RS) and ridge-expansion (RE) groups

	Total perforation area (mm^2)	Perforation occurrence (%)
RS group	315.65	55.56
RE group	99.27	27.77

Table 3 Initial crestal ridge width and width gain in self-tapping implant group and cylinder-type implant group

	Initial crestal ridge width (mm)	After implant insertion (mm)	Width gain (mm)
Self-tapping implant group (NobelActive)	2.79 ± 0.49	4.76 ± 0.75	1.97 ± 0.66
Cylinder-type implant group (Straumann Bone Level)	2.98 ± 0.53	4.61 ± 0.43	1.62 ± 0.58
	Paired *t* test, $P = .26$*		Paired *t* test, $P = .10$**

*No statistically significant difference of initial width ($P > .05$) between self-tapping and cylinder-type implant groups.
**No statistically significant difference in crestal width gain ($P > .05$) between self-tapping and cylinder-type implant groups.

Table 4 Mean of initial crestal ridge width of nonperforation cases after ridge-splitting and ridge-expansion procedures

	Initial ridge width at crestal level (mm)
Ridge-splitting group	3.16 ± 0.37
Ridge-expansion group	3.09 ± 0.41
Mean ± SD	3.12 ± 0.39

It is also important to note that the ridge perforated more frequently at certain locations in both groups. On average, 77.8% of cases had perforations in the area within 3 mm of the crestal site. The occurrence of perforation gradually decreased apically. It decreased to 5.6% at 10 mm apical from the crest.

Discussion

The preclinical narrow alveolar ridge experiment can be important for adjusting to actual patient conditions. In this study, the results of ridge-expansion or ridge-splitting techniques had no statistically significant difference in crestal ridge width gain. Nevertheless, ridge expansion with the motor-driven ridge expansion technique had fewer incidences of perforation compared to the ridge splitting with the piezosurgical technique, whereas the piezosurgical technique has been proposed to utilize micrometric cutting (with a precise and secure action to limited tissue damage).[25] The increased incidence of perforations with the piezosurgical technique may relate to the insert diameter. The thinnest piezosurgical insert available for implant site preparation (IM2P) was 2.0 mm at that time, which is relative wide in the extremely narrow ridge.

The active-tapping implant with variable thread design has some additional self-drilling capacity as well as axial and radial bone compression.[24] The threads of the NobelActive implant have been designed to act as osteotomes condensing the bone as the implant is being placed. The design makes it possible to place the implant into the narrower osteotomy and requires less drilling as compared with a cylinder-type implant. The macrostructure (shape) of implants in reference to parallel (cylinder) or self-tapping (tapered) implants could also affect the result of ridge expansion/splitting,[26–28] although it was difficult to conclude that active-tapping implants were superior to the cylinder-type in ridge width gain. The result of this animal study demonstrated that the active-tapping implant placement with the motor-driven ridge expansion technique achieves less total perforation area and less occurrence of perforation.

The ridge perforated more frequently at the crestal area in both groups. It may be relative to the morphology of the swine jaw, which is narrow at the crest and wider at the base. With understanding of this anatomical benefit, it can provide guidance for clinicians to select an appropriate candidate on whom to perform ridge-splitting/expansion techniques.

Conclusions

Ridge-splitting/expansion techniques can reduce surgical complexity and allow for implant placement in narrow alveolar ridges for proper prosthetic and esthetic outcomes. It is important to note that a minimum initial width (3.12 ± 0.39 mm) is recommended to achieve less perforation and more predictable ridge-expansion/splitting outcomes with a small-diameter implant. The combination of the motor-driven ridge expansion technique and the active-tapping implant could be beneficial for significantly decreasing the perforation area, thus minimizing the amount of bone grafting needed in clinical conditions.

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