Crestal Approach for Maxillary Sinus Augmentation in Patients with ≤4 mm of Residual Alveolar Bone

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ABSTRACT

Purpose: Less morbidity is the major advantage to a one-stage crestal approach to maxillary sinus elevation. However, the ability to ensure high primary implant stability in a severely atrophied ridge is of chief concern. The purpose of this study is to measure and compare the success rate of implants placed at the time of crestal approach sinus lift in patients with ≤4 mm of residual alveolar bone (RAB) and >4 mm of RAB.

Materials and Methods: In this three-site multicenter study, one hundred two patients, 53 males and 49 females, (23–89 years old; mean = 56.2) were evaluated. Three experienced surgeons (>15 years) performed the crestal approach sinus lift microsurgeries with simultaneous implant placement. At baseline and at the follow-up appointments, calibrated examiners measured radiographic interproximal bone level using ImageJ for Windows after calibration of the radiographs. References for the bone level measurements were the platform, first and second threads of the implants. Statistical analyses, using STATA version 12, stratified patients according to RAB height (group 1: RAB of ≤4 mm; $n = 35$ and group 2: RAB > 4 mm; $n = 67$), age, gender, and treatment center.

Results: The success rate was 100% for group 1 and 98.51% for group 2 at 6 to 100 months postprosthetic loading (mean = 29.7 months). The peri-implant bone loss averaged 0.55 mm (interquartile range [IQR] = 0.5 [0–1]) in group 1 and 0.07 mm (IQR = 0 [0–0]) in group 2. There was no statistically significant difference between the two groups. Clinical outcomes were independent of age, gender, and treatment center.

Conclusions: The RAB height did not increase crestal bone loss or reduce the success rate of the implants and associated prostheses. The crestal approach should be considered a viable technique for use in patients with residual bone height of ≤4 mm and merits further evaluation.

KEY WORDS: bone graft, crestal approach, implant, sinus graft

BACKGROUND

The most recent National Health and Nutrition Examination Survey reported that only 30.5% of the dentate population had a full complement of 28 teeth. Partial edentulism was more prevalent in the maxillary arch, and the most commonly missing teeth were the first and second molars.[1]

The loss of maxillary posterior teeth may be associated with pneumatization of the maxillary sinus into the edentulous area. The floor of the maxillary sinus is composed of basal bone and alveolar bone. Following extraction, the increased osteoclastic activity of the sinus membrane contributes to the resorption of the basal bone, whereas the loss of marginal bone contributes to the resorption of the alveolar bone. The rate of bone loss is generally fastest during the first 6 months after extraction.[2] As the ridge is resorbed externally, new bone is

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formed internally, maintaining a layer of cortical bone at the crest of the alveolar ridge.[2]

The lateral antrostomy and the crestal approach are commonly used techniques for augmentation of the maxillary sinus. The lateral antrostomy involves the elevation of the schneiderian membrane through preparation of a window in the lateral wall of the maxillary sinus.[3] The crestal approach involves utilizing tapered osteotomes with increasing diameters for creating an osteotomy for the selected implant. By gently tapping the osteotome in a vertical direction, the floor of the maxillary sinus is fractured and the membrane is simultaneously lifted.[4] Both techniques allow the space beneath the membrane to be grafted using several different materials.

The more conservative crestal approach has several advantages over the lateral antrostomy, which include reduction of operation time, trauma, and postoperative morbidity.[5] Historically, the use of this technique was limited to patients with at least 5 mm of residual alveolar bone (RAB).[6,7] In light of the numerous benefits bestowed to the patient with the use of the crestal approach, there is a great interest in expanding its applicability. This study was performed to provide evidence in support of the use of crestal approach with simultaneous implant placement in patients with residual bone height of 2 to 4 mm.

MATERIALS AND METHODS

Patients

The study was approved by the University of Southern California Institutional Review Board (UP-09–00081). A total of one hundred two patients, 53 males and 49 females, ranging from 23 to 89 years of age (mean = 56.2 years old) were assessed in the study. The patients were divided into two groups based on RAB height (group 1: RAB of ≤4 mm; $n = 35$ and group 2: RAB > 4 mm; $n = 67$). Patients diagnosed with acute sinus infection or significant systemic chronic conditions were excluded.

Surgical Procedures

In this three-site multicenter study, three experienced surgeons (>15 years) had performed the crestal approach sinus lift microsurgeries with simultaneous implant placement. A total of one hundred nine implants were placed at the time of the sinus lift procedure. The elevation forces facilitated membrane detachment without exceeding its deformation capacity, so that no perforations occurred.[8] For the patients who received alloplast, two tubes of 0.25 cc beta-tricalcium phosphate-coated hydroxyapatite (Osteon, Dentium USA, Cypress, CA, USA) with 0.5 to 1.0-mm particle size were placed underneath the elevated membrane using a 3.0-mm diameter osteotome (Genoss, Gyeonggi R&DB Center, Yeongtong-gu, Suwon-si, Gyeonggi-do, Korea). For the patients who received autogenous particulated graft, the bone was harvested form the adjacent surgical site or the mandibular retromolar area and was inserted into the osteotomy site. Prosthetic surgical guides were used to locate implants insertion sites. Straumann, Nobel Biocare, and Dentium systems were used for implant placement, and a primary stability of 25 to 45 Ncm was achieved for all implants (Straumann, Andover, MA, USA; Nobel Biocare USA, LLC, Yorba Linda, CA, USA; Dentium USA, Cypress, CA, USA; Dentium Korea, Samsung-dong, Gangnam-gu, Seoul, Korea). Prostheses were delivered after 6 months of healing.

Postsurgical Procedures

Oral and written postoperative instructions were given to all of the patients. Patients were instructed to take two 500 mg capsules (1 g) of amoxicillin starting 1 hour prior to the surgery and to take one 500 mg capsule every 8 hours for 7 days thereafter. Additionally, patients were instructed to take pseudoephedrine for 1 week after the surgery, and 600 mg of ibuprofen every 6 hours for pain. Sutures were removed 1 week after the surgery.

Radiographic Analysis

At baseline and the follow-up appointments, independent, calibrated examiners measured radiographic interproximal bone level using standardized digital periapical and three-dimensional intraoral radiographs. Three-dimensional radiographs provided quantitative information on maxillary sinus anatomy. Preoperatively, the bone height that could be achieved was estimated. Periapical radiographs were obtained with a dental X-ray machine operating at 60 kVp, perpendicular to the long axis of the implants with a long-cone parallel technique on a template. Mesial and distal marginal radiographic bone level changes were recorded using ImageJ for Windows (National Institutes of Health [NIH], Bethesda, Maryland, USA), which calculates area and pixel value statistics for user-defined selections. Spatial calibration was set to express dimensional units

in millimeters. The platform of the implant served as a reference to the radiographic bone level. The fixture threads served as an internal reference. Bone level was measured as the distance from the platform of the implant to the crest of the bone. Presurgical and postsurgical radiographic evaluations of the implant was performed. For each follow-up appointment, the radiographic change in the interproximal bone level was numerically calculated by comparing the previous level with the current level (see Figures 1–3).

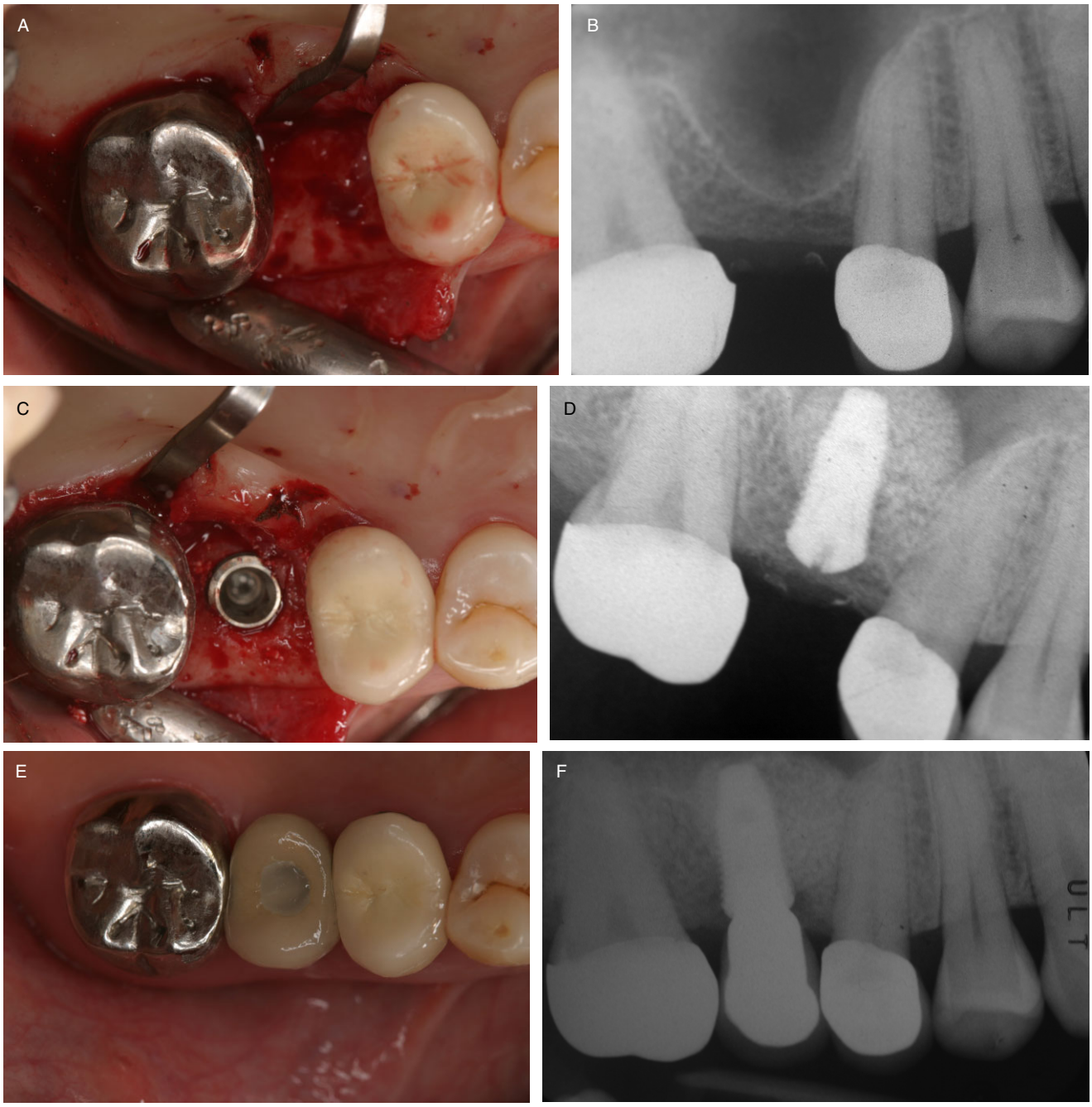

Figure 1 *A* and *B*, Clinical photograph and periapical radiograph taken prior to crestal approach sinus lift and simultaneous implant placement. Note the severity of maxillary sinus pneumatization prior to sinus lift procedure. *C* and *D*, Clinical photograph and periapical radiograph taken immediately after crestal approach sinus lift using beta tricalcium phosphate and simultaneous implant placement. *E* and *F*. Clinical photograph and periapical radiograph taken at the time of crown installation at 9 months after sinus grafting.

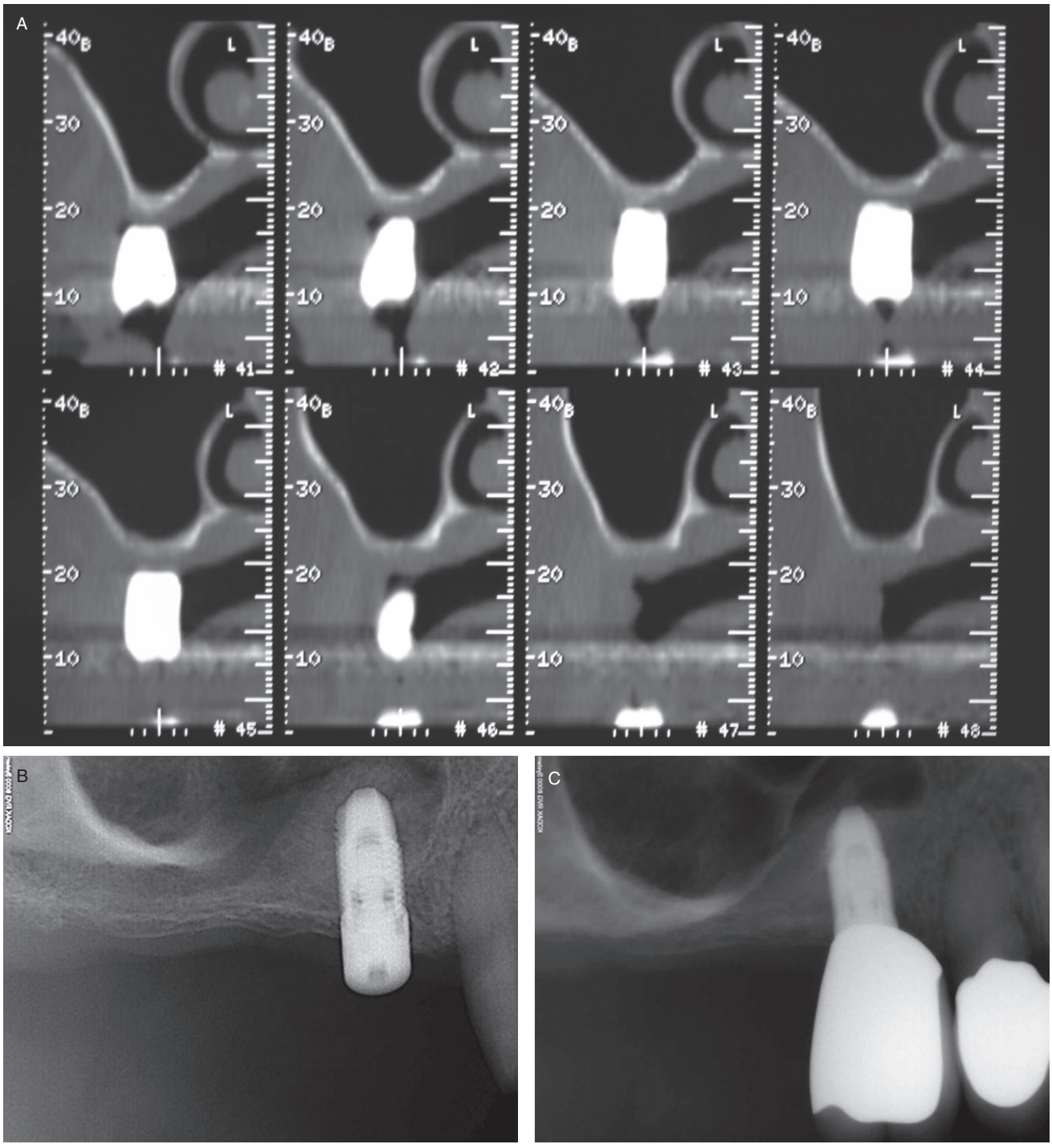

Figure 2 *A*, Computerized tomography scan measuring <2 mm of residual alveolar ridge height at the site of future implant placement. *B*, Periapical radiograph taken at the time of crestal approach sinus lift using intraoral bone as the graft matieral and simultaneous implant placement. *C*, Periapical radiograph taken at the time of crown installation, 8 months postsinus grafting and simultaneous implant placement.

Statistical Analyses

Data are compiled from three treatment centers: Seoul, Taipei, and Los Angeles. Of those patients with more than one implant ($n = 6$), all but one of the implants were randomly deleted from analysis. Subjects were grouped by RAB level using ≤4 mm and >4 mm as the grouping criteria. Age was categorized by 10-year age group (20–30, 31–40, 41–50, 51–60, 61–70, 71–80, 81–90). Because crestal bone loss of 2 mm or less is a common finding, 2 mm was used as the cutoff

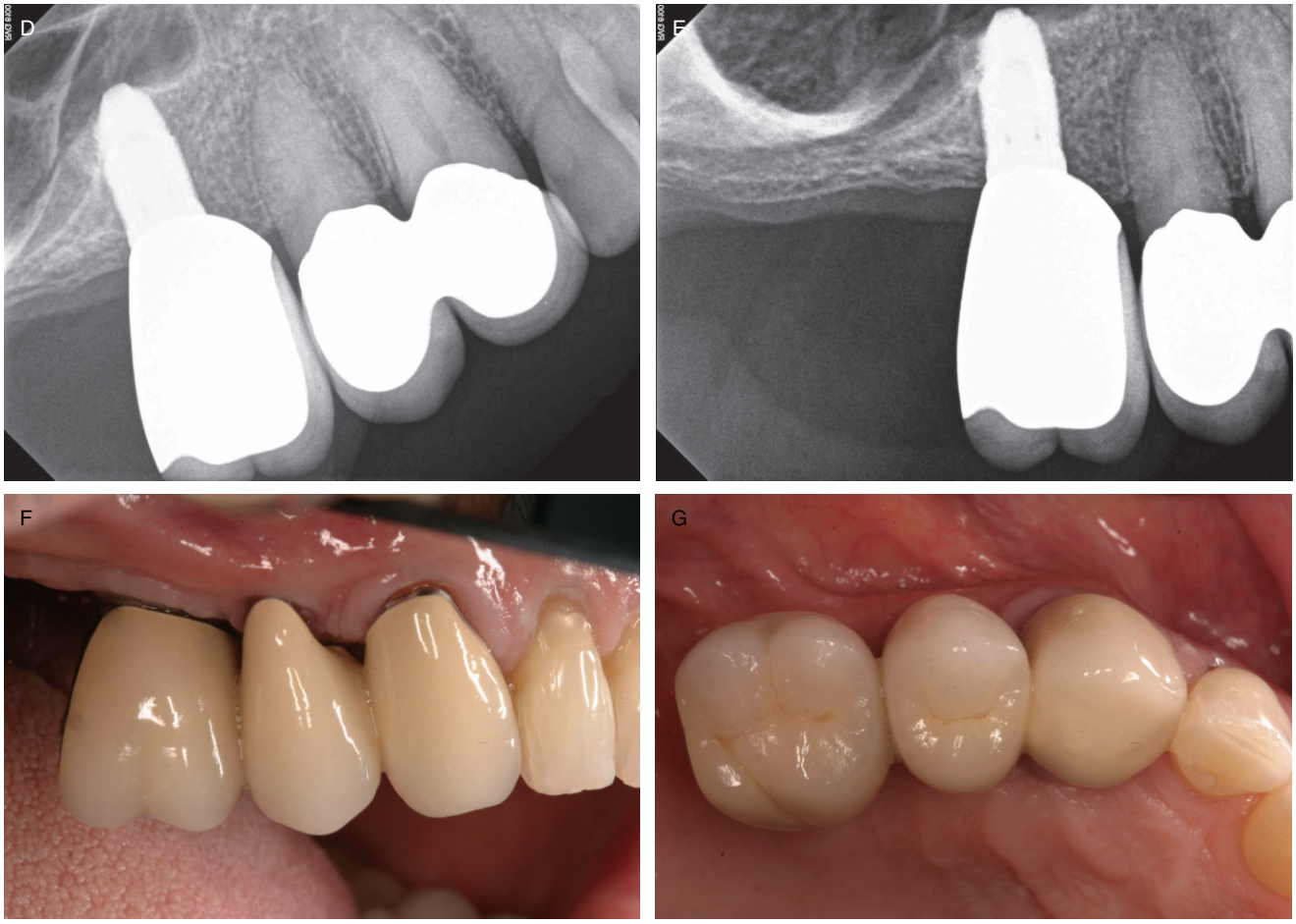

Figure 2 (*continued*) *D* and *E*, Periapical radiographs taken at 3 and 4 years postloading. Note crestal bone stability and apical shifting of maxillary sinus floor as a result of sinus grafting. *F* and *G*, Buccal and occlusal view of the final restoration in place at 4 years.

for evaluating bone loss. No subject had >2 mm of radiographic bone loss. Consequently, only descriptive analyses were performed. Quartiles of bone loss were obtained by age, gender, and center, and all analyses were performed using STATA version 12 (StataCorp LP, College Station, TX, USA).

RESULTS

There were no adverse events observed clinically in the oral tissues or the maxillary sinus. No sinus membrane perforation was detected. A total of one hundred nine implants were placed in one hundred two patients. Forty implants were placed into the patients in group 1, and 69 implants were placed into the patients in group 2. With the exception of one implant failure from group 2, all implants were clinically successful. The cumulative success rate was 100% for group 1 and 98.51% for group 2, after a period of 6 to 100 months (mean = 29.7) of loading. The mean sinus membrane elevation achieved in the patients in group 1 was 8.76 mm and 3.96 mm for the patients in group 2.

The patients in group 1 lost a mean of 0.55 mm (interquartile range [IQR] = 0.5 [0–1]) of crestal bone, and the patients in group 2 lost a mean of 0.07 mm (IQR = 0 [0–0]) of crestal bone over 6 months to 8 years of loading. There was no statistically significant difference in crestal bone loss between the two groups of patients. Clinical outcomes were independent of age, gender, and ethnicity (Tables 1–4).

DISCUSSION

The present study compared sinus augmentation via crestal approach with simultaneous implant placement in patients with ≤4 mm of RAB versus those with >4 mm of RAB. A total of one hundred two implants were placed in 96 consecutive patients with an equal gender distribution and a wide age range. No complications were encountered throughout the study, and

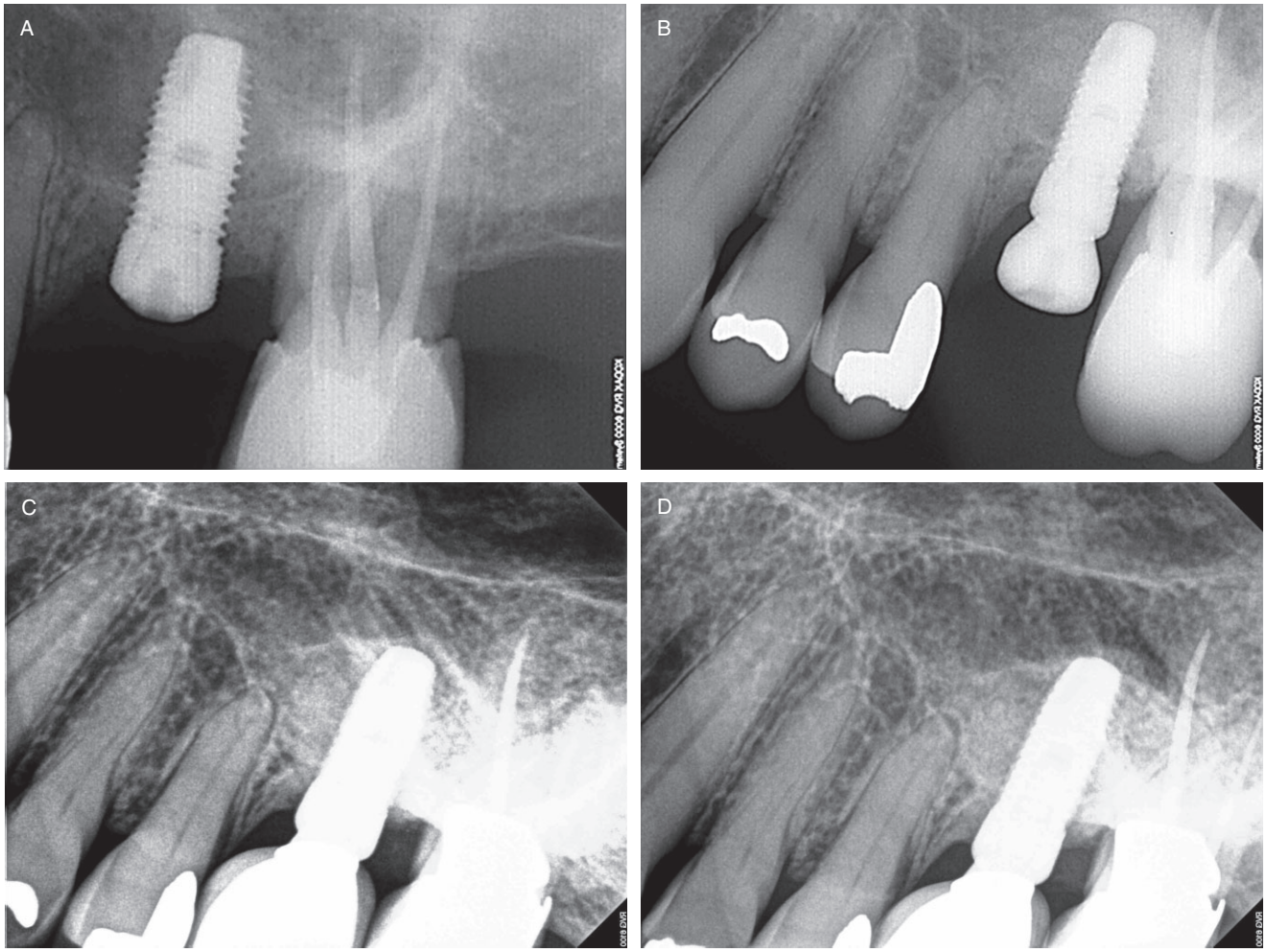

Figure 3 *A,* Periapical radiograph taken at the time of sinus grafting using autogenous bone from intraoral source and simultaneous implant placement. Note the height of the crestal alveolar bone. *B*, Periapical radiograph taken at the time of abutment connection. Note the height of the crestal alveolar bone. *C*, Periapical radiograph taken at the time of crown insertion. *D*, Periapical radiograph taken at 3 years after implant placement. Note new bone formation within the maxillary sinus surrounding the implant body.

the technique was performed with relative ease in all patients.

The results obtained compare favorably with the findings from a similar study by Winter and colleagues, in which 58 implants were placed into a severely resorbed ridge, with less than 4 mm of residual bone height. The sinus lifts were accomplished via the LMSF technique (localized management of the sinus floor technique), and the implants were placed immediately. The authors found an implant success rate of 91.4% after 22 months of loading.[9]

However, Rosen and colleagues reported that the survival rate of implants dropped significantly from 96% to 85.7% when RAB height was 4 mm or less. According to their findings, the most influential factor affecting implant survival was the height of bone from the crest of the alveolar ridge to the sinus floor.[7] More recent studies have found increased success rates with

TABLE 1 Bone Loss for Groups 1 and 2

RAB	*n*	Mean	SD	Min	0.25	Median	0.75	Max	Interquartile Range (IQR)
≤4	35	0.55	0.63	0	0	0.5	1	2	0.5 (0–1)
>4	66	0.07	0.2	0	0	0	0	1	0 (0–0)

TABLE 2 Bone Loss for Groups 1 and 2 Separated into 10-Year Age Cohorts

Age Group	*n*	Mean	SD	Min	0.25	Median	0.75	Max	Interquartile Range (IQR)
RAB ≤ 4									
20–30	0	–	–	–	–	–	–	–	
30–40	4	0.25	0.5	0	0	0	0.5	1	0 (0–0.5)
40–50	7	0.19	0.34	0	0	0	0.5	0.84	0 (0–0.5)
50–60	6	0.25	0.61	0	0	0	0	1.5	0 (0–0)
60–70	11	0.73	0.61	0	0	0.5	1.5	1.5	0.5 (0–1.5)
70–80	4	1	0.71	0	0.5	1.25	1.5	1.5	1.25 (0.5–1.5)
80+	3	1.13	0.78	0.5	0.5	0.9	2	2	0.9 (0.5–2)
RAB > 4									
20–30	5	0	0	0	0	0	0	0	0 (0–0)
30–40	4	0	0	0	0	0	0	0	0 (0–0)
40–50	12	0.03	0.09	0	0	0	0	0.3	0 (0–0)
50–60	18	0.1	0.26	0	0	0	0	1	0 (0–0)
60–70	13	0.02	0.08	0	0	0	0	0.3	0 (0–0)
70–80	13	0.08	0.19	0	0	0	0	0.5	0 (0–0)
80+	1	1	–	1	1	1	1	1	1 (1–1)

simultaneous implant placement and sinus lift via the crestal approach in patients with residual bone height of 4 mm or less. In 2006, Peleg and colleagues found a survival rate of 97.9% for implants placed immediately in the grafted maxillary sinus, where less than 5 mm of bone remained.[10]

There are several advantages to a one-stage approach to maxillary sinus floor elevation and implant placement, including reduced treatment time and elimination of the need for a second surgical procedure.[11] However, the ability to ensure a high primary stability in a severely atrophied ridge is of chief concern. Several

TABLE 3 Bone Loss for Groups 1 and 2 Separated into Gender Cohorts

Gender	*n*	Mean	SD	Min	0.25	Median	0.75	Max	Interquartile Range (IQR)
RAB ≤ 4									
Male	19	0.65	0.68	0	0	0.5	1.5	2	0.5 (0–1.5)
Female	16	0.43	0.57	0	0	0	0.95	1.5	0 (0–0.95)
RAB > 4									
Male	33	0.08	0.26	0	0	0	0	1	0 (0–0)
Female	33	0.05	0.14	0	0	0	0	0.5	0 (0–0)

TABLE 4 Bone Loss for Groups 1 and 2 Separated into Treatment Center Cohorts

Treatment Center	*n*	Mean	SD	Min	0.25	Median	0.75	Max	Interquartile Range (IQR)
RAB ≤ 4									
Seoul	5	0.6	0.65	0	0	0.5	1	1.5	0.5 (0–1)
Taipei	15	0.12	0.31	0	0	0	0	0.9	0 (0–0)
Los Angeles	15	0.97	0.61	0	0.5	1	1.5	2	1 (0.5–1.5)
RAB > 4									
Seoul	53	0.07	0.22	0	0	0	0	1	0 (0–0)
Taipei	13	0.07	0.13	0	0	0	0	0.3	0 (0–0)
Los Angeles	0	–	–	–	–	–	–	–	

studies have described that the initial stability of the implants is provided by the ubiquitous presence of cortical bone at the crestal aspect of the ridge. Cardaropoli and colleagues described the presence of the cortical bone layer consistently covering the marginal portion of a healing extraction socket at 60, 90, and 180 days.[12] Ohnishi and colleagues also described the corticalization of the alveolar bone, which provided a consistent layer of cortical bone at the crestal aspect of the ridge.[13]

The ability to elevate the schneiderian membrane, without perforation, utilizing the crestal approach was consistently observed throughout the study. In addition to thorough sinus anatomy evaluation, membrane detachment force, angle of instrumentation, and elasticity and deformation capacity assessment are all important factors to consider. Additionally, the number of insertion sites can increase the elastic properties of schneiderian membrane for more elevation height. Berengo and colleagues evidenced that sinus anatomy, as well as elastic properties of the schneiderian membrane, correlate with the maximum elevation height that is achievable.[14] In the present study, detachment was gradually reduced at the center and targeted membrane circumference. Several authors have reported elevation of the sinus membrane to heights of 2.5 mm to 8.6 mm, employing the crestal approach.[11,15–19] However, crestal approach cannot be performed in all cases. Perforation may lead to postoperative maxillary sinusitis or graft migration into the sinus. Crestal approach requires a thorough assessment of the anatomy, elasticity, and deformation capacity of the membrane and precise surgical approach.

The necessity for use of graft materials for maxillary sinus floor elevation is controversial. Several authors have described successful maxillary sinus floor elevations without the use of graft materials. In 2007, Thor and colleagues performed sinus floor elevations without grafting material and found an implant survival rate of 97.7% and a mean bone gain of 6.51 mm after a minimum follow-up of 1 year.[20] Bone formation around implants within the sinus has been reported without the use of bone grafting or biomaterials in animal and human studies alike.[11,21,22]

When a graft material is to be used, autogenous bone remains the gold standard for augmentation of the maxillary sinus. However, autologous bone undergoes extensive resorption,[23] which may be associated with contamination from intraoral pathogens.[24] The graft materials used in this study were autogenous bone and beta-tricalcium phosphate-coated hydroxyapatite. Beta-tricalcium phosphate resorbs at a relatively slow rate and effectively maintains the sinus membrane elevated throughout the healing process. Its resorption is less than that of autogenous bone[25] and does not require a second surgical site.[26] In the present study, both techniques provided the same success rate.

The findings of the present study suggest that the crestal approach for maxillary sinus floor elevation is a viable technique for use in patients with minimal residual bone height, of ≤ 4 mm, in the edentulous posterior maxilla. Further clinical and in vitro investigations are needed to measure the mechanical properties of the schneiderian membrane, minimum force needed for its detachment from the underlying bone and its elasticity and load limits.[8] In spite of the known limitations encountered in a retrospective study, the favorable results obtained merit further studies that examine the long-term outcome of implants placed under these conditions.

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