Healed Edentulous Sites: Suitability for Dental Implant Placement, Need for Secondary Procedures, and Contemporary Implant Designs

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Purpose: The purpose of this retrospective computed tomography study was to evaluate bone availability for dental implant placement, frequency of bone augmentation procedures, frequency of anatomical structures that compromise implant placement, and frequency of implant dimensions, and to determine which edentulous sites would benefit from the use of a sloped implant versus a traditional flat design. Materials and Methods: Recorded parameters included the width of the ridge, the buccal and lingual/palatal alveolar bone height in reference to different anatomical landmarks, determination of implant placement, selection of an implant with a flat or sloped top, and need for a secondary bone augmentation procedure. Results: One thousand three hundred seventy edentulous sites were evaluated in 216 patients. Implants could be placed in 60.6% of the total sites, where the coronal portion would be sloped in 59% of sites and conventionally flat in 41%; 39.4% of sites were not adequate for implant placement, where 56.5% needed additional guided bone regeneration procedures and 43.5% required sinus augmentation procedures. The inferior alveolar canal was the most frequent anatomical structure limiting size and/or placement. Conclusion: The study indicates that implants can be placed in slightly over half of edentulous sites without a secondary grafting procedure. The possibility of dental implant placement varied according to the volume and morphology of alveolar bone and related anatomical structures. This decreased from anterior to posterior in both arches. The sloped implant design was beneficial. In addition, the sloped implant design resulted in the placement of a longer implant. Int J Oral Maxillofac Implants 2020;35:924–930. doi: 10.11607/jomi.8215

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ostectomy. When the clinician has been able to remove the osseous structure, guided bone regeneration with simultaneous or delayed implant placement has been suggested. These standard procedures have been utilized to accommodate a standard flat-topped dental implant body. A sloped implant top has been developed (OsseoSpeed Profile Implant, Astra Tech). The sloped design enables the placement of the implant in an uneven ridge without ridge reduction or additional procedures.

The purpose of this computed tomography study was to evaluate bone availability for dental implant placement in the partially or totally edentulous patient, frequency of need for bone augmentation procedures, frequency of commonly found anatomical structures that could compromise implant placement, and the frequency of different implant dimensions, and to determine what percentage of edentulous sites would benefit from the use of this sloped implant design compared with the traditional flat design.

MATERIALS AND METHODS

The study protocol was approved by the University of Pennsylvania Institutional Review Board. Computed tomography scans of patients with native edentulous sites needing osseous dental implant placement for oral rehabilitation were evaluated as a component of a clinical dental implant study. Based on the tomographic images, previously calibrated examiners evaluated the different sections of edentulous sites to be restored in order to determine the possibility for dental implant placement. Measurements in millimeters included ridge width and buccal and lingual/palatal height. In addition, the location of anatomical structures including the inferior alveolar canal, mandibular symphysis, nasal floor, maxillary sinus floor, nasopalatine foramen, and concavity were identified (Fig 1).

In the edentulous sites, two different implant designs were compared for optimum placement dependent on bone quantity with the use of standardized templates provided by the implant manufacturer (Astra Tech) that replicated the outer shapes of the respective implants. The first was an implant with a sloped coronal portion design (OsseoSpeed Profile Implant, Astra Tech), and the second was a more conventional dental implant with a traditional flat top (OsseoSpeed Implant, Astra Tech; Fig 2). The length of implants was determined by selecting the implant that most closely approximated the cortical border of a sinus. In the case of the inferior alveolar canal or a foramen, the implant length was determined by the nearest implant that was not closer than 3 mm. Dental implants were required to have a minimum of 1 mm around the diameter with either a 4.5- or 5.0-mm-diameter implant.

In the sites where it was determined that dental implant placement was not possible, guided bone regeneration or maxillary sinus augmentation procedures were selected as the optimal treatment option. Measurements of bone height, dental implant sizes, anatomical structures, availability for dental implant placement, implant position, and type of implant configuration were compared.

Statistical analysis consists of a general description for continuous variables (mean, standard deviation, range, and median), but also differentiating by group. Categorical variables were described by means of absolute and relative frequencies. The inferential analysis included all the statistical tests required to study rates of adequacy and frequency of types of implants, as well as the influence of the position and anatomical structures. This included binomial tests; binary logistic regression models using generalized estimation equations were performed. Effects of predictors were estimated by means of Wald’s chi² statistic. Odds ratio (OR) estimations and corresponding 95% confidence intervals were obtained. The significance level used in analysis was 5% (α = .05).

Fig 1 Anatomical considerations including (a) inferior alveolar nerve, (b) pneumatized maxillary sinus, (c) mandibular lingual undercut, (d) incisive canal, (e) inferior alveolar nerve and mandibular lingual undercut, and (f) pneumatized maxillary sinus and buccal concavity, which prohibited dental implant placement.
A total of 216 patient CBCT scans were included for analysis. The CT scans contained a total of 1,370 edentulous sites (Table 1). Each patient had a mean of 6.34 sites. Anterior sites were defined as canine to canine. Posterior sites included positions from the first premolar moving distally. There were 727 (53.1% of total sites) maxillary sites, of which 205 were anterior (15% of total; 28.2% of maxillary sites) and 522 were posterior (38.1% of total; 71.8% of maxillary sites). There were 643 (47% of total sites) mandibular sites, of which 99 were anterior (7.2% of total sites; 15.4% of mandibular sites) and 544 were posterior (39.7% of total sites; 84.6% of mandibular sites). Overall, there were a total of 304 anterior and 1,066 posterior edentulous sites.

When the ridge dimensions were evaluated, the mean buccal bone height was 10.2 ± 4.9 mm, the mean lingual bone height was 10.3 ± 4.8 mm, and the mean bone width was 7.1 ± 2.6 mm. In the maxillary anterior area, the mean buccal bone height was 13.03 mm, the mean lingual height was 12.37 mm, and the mean width was 5.33 mm. In the posterior sections of the maxilla, the mean buccal bone height was 8.73 mm, the mean lingual bone height was 8.52 mm, and the mean width was 8.06 mm. The mean buccal bone height in the mandibular anterior area was 13.59 mm, the mean lingual height was 13.47 mm, and the mean width was 6.9 mm. Finally, in the posterior sections of the mandible, the mean alveolar buccal bone height was 10.18 mm, the mean lingual alveolar bone height was 11.01 mm, and the mean width was 7.49 mm.

In 94% of the sites studied, some anatomical structures were identified. Anatomical structures that impact dental implant length and/or placement included the inferior alveolar canal with 456 sites (33.3% of total), followed by the maxillary sinus with 432 sites (31.5% of total), nasal floor with 176 sites (12.9% of total), mandibular symphysis with 39 sites (3.8% of total), alveolar concavity with 35 sites (2.6% of total), and nasopalatine foramen with 5 sites (0.4% of total; Table 2). When compared, the inferior alveolar canal (P < .001) and maxillary sinus (P < .004) were both statistically significantly greater than the other anatomical structures as limiting factors for implant placement.

A combination of anatomical concerns were also recorded and included the inferior alveolar canal/lingual concavity (67 sites/4.9% of total sites), nasal floor/nasopalatine canal (26 sites/1.9% of total sites), maxillary sinus/nasal floor (25 sites/1.8% of total sites), alveolar...
concavity and nasal floor at 10 sites (0.7% of total), mandibular symphysis/alar concavity (7 sites/0.7% of total sites), and a combination of the maxillary concavity, maxillary sinus, and nasal floor at 1 site (0.07% of total sites). The inferior alveolar canal/lingual concavity was statistically significantly greater than the other anatomical combinations ($P < .05$).

A total of 830 (60.6%) out of 1,370 sites had sufficient bone for dental implant placement after considering bone height/width and/or anatomical structures. The frequency of suitable sites for implant placement was significantly greater than those in which an implant could not be placed ($P < .001$). Four hundred ninety-three (59%) of these edentulous sites could receive a sloped implant body, and 337 (41%) could receive a standard implant body design. There was insufficient bone volume for dental implants in 540 sites (39.4% of total sites; Table 3). Three hundred five (22.3%) from total and 56.5% from nonimplant sites) of these sites would require guided bone regeneration procedures, and 235 sites (17.2% from total and 43.5% from nonimplant sites) would require sinus augmentation procedures. There was a statistically significant difference between the number of sites with sufficient bone for a dental implant compared with the sites that were inadequate ($P < .05$).

In the maxilla, a total of 359 sites (43.3% of total implant sites) were adequate for implant placement, whereas 368 sites (68.1% of total nonimplant sites) were not adequate for implant placement. In the mandible, a total of 471 sites (56.7% of total implant sites) were adequate for implant placement, whereas 172 sites (31.9% of total nonadequate implant sites) were not adequate for implant placement. The comparison of arches demonstrated a statistically significant difference between the maxilla and mandible, where more implants could be placed in the mandible ($P < .05$).

Dental implant placement significantly depended on position, where anterior sites were greater than posterior sites ($P < .05$). In general, the rate of implant placement in the anterior versus posterior was dependent on the presence of an anatomical structure ($P < .05$). Specifically, the presence of the maxillary sinus and/or concavity decreased the rate of implant placement.

Overall, of the 830 sites that had adequate bone for a dental implant, 40.6% (337) could accommodate the sloped design and 59.4% (493) could receive a standard implant. There was a statistical difference between the sites that could receive a sloped versus a standard body design ($P < .001$). Regarding the 229 sites (27.6% of total adequate implant sites) that could receive a dental implant in the posterior maxillary area, 131 (36.5% of maxillary sites and 15.8% of total adequate implant sites) benefited from a sloped top and 98 (27.3% of maxillary sites, 11.8% of total adequate implant sites) could receive a standard design. A comparison demonstrated that the sloped-top implant was statistically greater than the standard design ($P < .05$). For the 389 mandibular posterior sites (46.9% of total implant sites), 233 (49.6% of total mandibular sites and 28.1% of total implant sites) benefited from a sloped-top implant design and 156 sites (33.1% of mandibular sites and 18.8% of total adequate implant sites) could receive a standard design. The sloped-top design was statistically significantly greater ($P < .05$). There were 77 (9.3% of total implant sites) anterior maxillary sites that could not receive a dental implant and 130 (15.7% of total adequate implant sites) that had adequate bone for dental implants. Eighty-eight sites (24.5% of maxillary sites and 10.6% of total adequate implant sites) would benefit more from a sloped-top implant design, and 42 sites (11.7% of maxillary sites and 5.1% of total adequate implant sites) would benefit more from a regular-body implant design. When compared, the sloped-top implant design could be utilized more than the standard design in the anterior maxilla ($P < .05$). Lastly, of the mandibular anterior sites, only 17 (1.2% of total number of sites) did not have sufficient bone for dental implants. Eighty-two sites (9.9% of total adequate implant sites) were adequate for implant placement, with 41 sites (8.7% of total mandibular sites and 4.9% of total adequate implant sites) benefitting from placement of a sloped-top implant design, and 41 sites (8.7% of total mandibular sites and 4.9% of total adequate implant sites) were adequate for placement of a standard implant design. There was no difference between implant designs in the anterior mandible ($P > .05$). Lastly, when implant configuration and dimensions were evaluated, the most common was the sloped-top implant with a 5 × 9-mm size (10%; n = 83; Fig 3). The least common was the regular-body configuration of 4.5 × 15 mm (0.2%; n = 2).

### Table 3 Number of Sites with Inadequate Bone That Require Guided Bone Regeneration or Sinus Augmentation

<table>
<thead>
<tr>
<th>Sites that require GBR</th>
<th>Sites that require sinus augmentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of sites</td>
<td>305</td>
</tr>
<tr>
<td>Percent of total sites</td>
<td>22.3</td>
</tr>
<tr>
<td>Percent of nonimplant sites</td>
<td>17.2</td>
</tr>
</tbody>
</table>

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DISCUSSION

In the present study, frequency of uneven healed alveolar ridges along with their proximity to different anatomical structures, possibility of additional surgical procedures, as well as a comparison between two different implant designs were evaluated. When considering the likelihood of dental implant placement, many of the sites required a secondary procedure. As the implant positions became more distal, the likelihood of this increased. Clearly, the position of the inferior alveolar canal and maxillary sinus were predominating factors in the availability of adequate bone. Moreover, the presence of limited bone height above the inferior alveolar canal in the posterior mandible increased the likelihood of a contraindication for implant placement. The ability to place a dental implant was enhanced when the body design was changed from a flat to a sloped top.

After tooth extraction or loss, the remaining alveolar bone will undergo a resorptive process. Several preclinical studies have documented the dimensional ridge changes following extraction of teeth. Araújo and Lindhe⁹ found that the buccal/lingual walls of an extraction site underwent two overlapping phases over an 8-week period. In phase one, the bundle bone was resorbed and replaced with woven bone. Later in the second phase, the outer walls of the extraction site were resorbed. In a similar study design, Cardaropoli et al¹⁵ demonstrated the importance of grafting the extraction site.¹⁵ When a xenograft was utilized, the defect exhibited less wound shrinkage. In a recent human study, Misawa et al¹⁶ found that the extraction of a maxillary incisor or premolar resulted in hard tissue loss.¹⁶ The resorption was greater on the buccal and marginal walls. Although greatly accentuated during the first year, there was continued long-term resorption.¹⁷ This residual bone resorption therefore plays a key role in the total final dimensions of the alveolar process.

The clinical implications as demonstrated in the present study indicate that anatomical structures may cause a contraindication to implant placement or need for a secondary grafting procedure. Huang et al¹⁸ found that anatomical concavities had a significant role in implant placement.¹⁸ In a similar sample size as the present study, CBCT evaluations indicated that the odds ratio for lingual plate perforations during immediate implant placement was 3.1%. As the implant site moved posteriorly, the odd ratios increased dramatically.

In recent years, the coronal aspect of the dental implant has undergone multiple changes in order to enhance bone maintenance. A significant amount of this development has been focused on the implant macrogeometry involving different thread designs and shapes. Generally, these alternatives have been adopted to preserve the maximum amount of crestal bone with subsequent soft tissue stability enhancing the final esthetic predictability of implant restorations. The placement of a standard flat-topped implant in an uneven healed ridge may carry different disadvantages depending on the clinician’s consideration at which alveolar bone depth placement should occur. When the implant is placed at the lingual bone height, the buccal portion of the implant will not be fully seated, resulting

![Fig 3](image-url) Number and length of sloped- or standard-top dental implants at sites with adequate bone.
in a risk for esthetic and maintenance complications. In situations where the implant is placed in reference to the buccal bone, the excessive amount of lingual bone height may need to be resected. In cases where this discrepancy is not equilibrated, an eventual bone resorption process will occur, reducing the height of the higher alveolar bone.\(^1\) The preservation of this height discrepancy following healing is also dependent on the magnitude of the difference that existed at the time of implant placement.\(^2\) The resorption of the higher alveolar plate described in these studies correlates with the increased bone healing resorption concurrent to regular implants placed in a submerged position. Therefore, the implant-abutment interface and subsequent microgap will be positioned below the alveolar bone crest.

A novel scalloped implant design (Nobel Perfect Esthetic Scalloped Implant) was described by Wöhrle.\(^3\) This design had a scalloped geometry that claimed to provide enhanced esthetics by maintaining the interimplant papillae through the creation or preservation of the bony peaks adjacent to the implant. However, several studies have demonstrated increased marginal bone resorption as well as little evidence of improvement in soft tissue height or contours.\(^4\)\(\text{–}\)\(^8\)

More recently, a different sloped implant design (OsseoSpeed Profile implant, Astra Tech) has been developed. The slope was not designed to maintain the interproximal bony peaks but to compensate for the height difference of the buccal and lingual/palatal bone crests. Abrahamsson et al\(^9\) compared this design to the standard flat-top implant.\(^9\) In this study, the two implants were placed in healed ridges in a canine model and evaluated clinically, radiographically, and histologically. It was concluded that both implant designs helped preserve the vertical discrepancy of buccal and lingual marginal bone. However, it was suggested that the tapered design should be used in these cases, as the regular implant design was unable to give the same support in this marginal bone portion. In a prospective multicenter clinical study, Noelken et al\(^10\) evaluated the soft and hard tissue alterations around the novel sloped implant design described in this article. The authors concluded that when placed in a site with ridge discrepancy, the sloped design contributed to only minor bone remodeling with the preservation of the marginal bone heights at both the buccal and lingual sides and soft tissue levels. In the present study, the use of the sloped implant provided several potential advantages. The sloped-top implant was able to better conform to the alveolar ridge. With the placement of the sloped implant, the practitioner will not need to perform an ostectomy. When bone removal does not occur, there will be less marginal bone resorption. Hence, there would be a reduction in exposed implant surface. A longer sloped implant could also be placed at the potential implant sites. The longer implant length may be critical in sites with limited bone height and may allow the placement of an implant that is not possible with a traditional design.

Overall, the study provides knowledge regarding confounding anatomical structures for dental implant placement, implant dimensions, and suitability of a site to accept a dental implant. However, the study was not without limitations. The study design included a limited number of implant dimensions. Specifically, diameters less than 4.5 mm may shift the percentages of sites that could not have a dental implant placed to a site that was suitable. In addition, the implant position was not prosthodontically driven. In general, prosthodontically driven implant positions tend to shift the implant body to where, for example, the buccal bone palate may be perforated. This would then require a secondary procedure causing a shift from a site that had adequate bone to one that could not have an implant placed.

CONCLUSIONS

The results of this study indicate that dental implants can be placed in slightly over half of edentulous sites without an adjunctive or secondary procedure. The possibility of dental implant placement varies dependent on location in the arches and the related anatomical structures. Height discrepancy between the buccal and lingual portions of the alveolar bone is a frequent finding in sites where teeth have been extracted or lost. The use of a sloped-top implant body design that will compensate for this difference is more frequently indicated than a standard flat-top implant design, therefore preserving the remaining marginal bone and reducing the number of possible surgical procedures. In addition, the placement of a longer implant was possible at a higher frequency with the sloped-top implant body.

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REFERENCES


