Why Guided When Freehand Is Easier, Quicker, and Less Costly?

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Computer-assisted implant planning and subsequent production of a surgical template based on this plan has gained attention because it provides restoratively driven esthetics, patient comfort, satisfaction, and the option of flapless surgery and immediate restoration. However, it adds expense and requires more time. Another significant but not so apparent advantage may be improved survival and success over freehand techniques in types III and IV bone. This retrospective analysis was undertaken to examine that possibility. It reports 1-year outcome for 80 implants in 27 consecutively presenting patients treated over a 7-year period using computer-assisted techniques across all bone qualities in commonly encountered treatment indications in private practice. Implants were placed to support single teeth, small bridges, and complete arch restorations in exposed or immediately restored applications, based on primary stability as determined by insertion torque, resonance frequency analysis, and Periotest. For the 80 implants supporting 35 restorations, the median observation period is 2.66 years; 73 implants supporting prostheses in 22 patients had readable radiographs at 1 year. There was a 1-year overall implant survival and a success rate of 100%. Radiographic analysis demonstrated the change in bone level from the platform at 1-year is less than 2 mm. Intra-operative median measurements of primary stability were insertion torque, 40 Ncm; resonance frequency, 76 ISQ; and Periotest, −3. All intra-operative measurements were consistent for acceptable primary stability regardless of bone density. Restoratively driven diagnosis and precision planning and initial fit were possible with computer-assisted techniques resulting in the achievement of high primary stability, even in areas of less dense bone. The ability to plan implant position, drill sequence, and implant design on the basis of predetermined bone density gives the practitioner enhanced pretreatment information which can lead to improved outcome.

Key Words: clinical research, guided, implant surgery, bone density, immediate load, osseointegration, success

INTRODUCTION

Implant dentistry is primarily practiced using freehand techniques with survival rates commonly higher than 90%. However, the freehand technique lacks the sophistication of restoratively driven concepts and management in types III and IV bone. Although the diagnostic computerized tomography (CT) scan has been utilized for many years, its use has been primarily for volume determination and approximation of tooth and critical anatomy relative to the potential implant site. However, this planning information is not precisely transferred to the patient for implant placement unless computer-assisted surgery (CAS) is utilized.

Guided implant dentistry was first introduced for fully edentulous patients, allowing flapless implant and restoration placement in the same visit.\textsuperscript{1} The concept is based on the transformation of a radiographic guide, which allows information on
preplanned tooth position in relation to the patient’s anatomy to be captured on the CT scan. When digitized, the information is transformed into a stereolithographic surgical template. This template incorporates sleeves that precisely guide drills and implant placement using information from the digital planning process and fabrication of pre-implant models for immediate restoration fabrication. More recently, this technique has been utilized for the replacement of single teeth and multiple teeth with much success.\textsuperscript{2–4}

Computer-guided or computer-assisted surgery (CAS) provides multiple advantages, as it allows biologically and restoratively driven planning plus the precision of implant position leading to improved esthetics, increased patient comfort and satisfaction, and potential for immediate restoration. However, it adds expense and requires more time. In our experience over the past 7 years using CAS, we have observed that there may be another significant benefit: improved survival and success over freehand techniques, especially in types III and IV bone. Therefore, this retrospective analysis was undertaken to examine that possibility.

**MATERIALS AND METHODS**

Twenty-seven consecutively presenting patients requesting immediate loading between 2006 and 2012 were treated with 80 implants using CAS and analyzed retrospectively. Prior to implant placement, each patient had a CT scan (GE LightSpeed or GE HiSpeed, or Discovery CT750 HD, GE Medical Systems, Waukesha, Wis) with an intra-oral radiographic guide in place, incorporating the teeth to be replaced (Figure 1).

The radiographic guide itself was separately scanned. The digital files (DICOM format) of both scans were converted in the planning software (NobelGuide, NobelBiocare, Yorba Linda, Calif) and implants were planned relative to the bone and teeth they would support (Figure 2). Following the planning, a surgical template was produced (Figure 3).

Those implants not immediately loaded were either exposed with healing abutments or submerged. All implants were followed up within at least 1 year with radiographic and clinical examination. The implant designs and sizes (NobelBiocare) were selected on the basis of the bone quality determined in the planning program according to the following criteria: the straight-walled MK III 3.75 mm in type I bone and MK III 4 mm for types II and III bone. In types III and IV bone, the tapered MK IV or Speedy 4 mm were selected for multiple implant restorations and posterior single teeth. For implants in the anterior regions, 3.5 mm internal connection straight in bone types I and II and tapered in types III and IV were selected.

**Placement**

All recipient sites were prepared and generally followed the manufacturers’ guidelines, but a few modifications were applied. The planning bone density was confirmed with the tactile sense of bone density using the 2 mm diameter drill. In type I bone, the final twist drill of 3.0 mm (0.75 mm less than the implant diameter) and tapping 3.0 mm short of full depth were used. In type II bone, the preparation was slightly undersized by 1 mm less than the implant diameter. In type III bone, the preparation was undersized by 1.2 mm and the depth preparation was to full depth with straight implants or 3.0 mm short of the apex of the tapered implants. In type IV bone, the preparations were undersized through the use of a final twist drill that...
was 1.25–2.0 mm narrower than the diameter of the planned implant for width preparation. For all implants, the implant platform was planned to be 0.7 mm below the crest of bone (Table 1).

Primary stability of implants was measured intraoperatively by three methods: Insertion torque value was obtained the hand torque wrench (NobelBiocare). Resonance frequency analysis was performed using a Resonance Frequency Analyzer (Model 6, Osstell AB, Gothenberg, Sweden). Periotest Value was measured at 4 mm above the implant platform on the implant mount. (Periotest, Medizintechnik Gulden, Modautal, Germany).

### Loading & follow-up

The implants were loaded immediately based on clinical requirements of the patients and intraoperative primary stability measures. Criteria for immediate loading were: insertion torque (IT) >35 Ncm, instability quotient (ISQ) >65, or periotest value (PTV), or C0 / C21 <0.

Implants that did not require immediate loading were either submerged or left exposed with healing abutments 0–2 mm coronal to the soft tissue. The decision to expose or submerge was based on the following criteria: submerge: IT <20 Ncm, ISQ ≤58, or PTV >0; and expose: IT >30 Ncm, ISQ >58, or PTV <0.

When implant placement through soft tissue would eliminate attached tissue, a mini-flap was made. Sutures were removed 8–14 days postoperatively. The immediately loaded screw-retained provisional prostheses were not removed for at least 3 months postoperatively in the mandible and 4 months in the maxilla. At the end of this osseointegration period, the immediately loaded restorations and the exposed healing abutments were removed, and the submerged implants were exposed. Implants were definitively restored with splinted fixed screw-retained resin or ceramic prostheses or, for single teeth, cement or screw-retained porcelain fused to high noble metal crowns. In 3 cases, the provisional prosthesis was not removed and functioning as the definitive prosthesis. After insertion of the final prostheses, the patients were asked to return every 3 months for maintenance.

Radiographic measurements were made from the implant platform to the most apical extent of bone adaptation on the mesial and distal sides of the implant. To measure bone height, radiographs were magnified and then calibrated using the actual platform diameter as compared to the diameter on the magnified radiograph.

Plaque Index and modified Gingival Index were graded on the buccal surface of the restoration at the mesial, midbuccal, and distal positions at least 1-year follow-up. Scores were averaged per implant.

Implants were considered successful when there was absence of pain, mobility, suppuration, and marginal soft tissue recession with the bone level relative to the implant platform being less than 2 mm at a minimum of 1-year follow-up.

### Statistical analysis

Retrospective data were analyzed using the Wilcoxon signed-rank test, the Kruskal-Wallace test, and Spearman’s rank correlation.

### Results

Eighty implants in 27 consecutively treated patients were followed from 56 to 382 weeks. Mandibular implants were osseointegrated by 12 weeks and maxillary implants by 16 weeks. Both survival and success rate is 100% with a median survival period of 139 weeks (interquartile range: 77–270 weeks). Among the 80 implants, 48 (60.0%) were immediate loaded, 30 (37.5%) were exposed, and 2 (2.5%) were
submerged. Twenty-seven (33.8%) were placed in the posterior mandible, 27 (33.8%) in the posterior maxilla, 13 (16.3%) in the anterior mandible, and 13 (16.3%) in the anterior maxilla (Table 2). The distribution of the restorations for these implants consisted of 33 (41.3%) supported complete arch fixed prostheses, 2 (2.5%) complete arch overdenture, 30 (37.5%) partial arches fixed prostheses, and 15 implants (18.8%) supported single restorations. Representative examples of clinical results are shown in Figure 4a, b, and c.

Intra-operative primary stability measurements are shown in Table 3. The median insertion torque value was 40 Ncm with interquartile ranges of 35 and 45. The median ISQ value was 76 with interquartile ranges of 60.7 and 71.5. The median PTV value was 0 with the interquartile ranges of –5 and –1. There is no

<table>
<thead>
<tr>
<th></th>
<th>Immediate Loaded</th>
<th>Exposed</th>
<th>Submerged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior maxilla</td>
<td>7 (8.8%)</td>
<td>6 (7.5%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Posterior maxilla</td>
<td>21 (26.3%)</td>
<td>6 (7.5%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Anterior mandible</td>
<td>5 (6.3%)</td>
<td>6 (7.5%)</td>
<td>2 (2.5%)</td>
</tr>
<tr>
<td>Posterior mandible</td>
<td>15 (18.8%)</td>
<td>12 (15%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td></td>
<td>48 (60%)</td>
<td>30 (37.5%)</td>
<td>2 (2.5%)</td>
</tr>
</tbody>
</table>

**TABLE 2**

Implants by treatment and location

In Figure 4. (a) Immediately loaded maxillary complete arch. (b) Maxillary partial arch. (c) Immediately loaded mandibular single tooth.
significant difference in the intra-operative measurements by location ($P = 0.31$, Kruskal-Wallis test).

Correlation among the three intra-operative measures for the 80 implants were estimated using the Spearman rank-based correlation, shown in Table 4. There was no significant correlation between ISQ and IT, and between PTV and IT. However, PTV and ISQ were significantly correlated with the coefficient $r = 0.33$ ($P < 0.0001$). Therefore, there is a trend that these measures relate to one another.

Radiographic results are shown in Table 5. Seventy-three (91.3%) of 80 implants had readable radiographs and available clinical measurements. The radiographic analysis demonstrated the median change in bone level from the platform at 1 year is 1.46 mm.

Soft tissue results are summarized in Table 6. The plaque and gingival index score were 0 for 66 (90.4%) and 59 (80.8%) implants, respectively; 1 for 5 (6.8%) and 14 (19.2%) respectively; 2 (2.7%) had a plaque index score of 3. These two implants with a plaque index score of 3 were in an overdenture restoration, and the plaque was seen on the prosthesis, so it scored as 3 (Table 6). The amount of plaque was not extensive on these implants; therefore, the gingival index score was 0. Overall, soft tissue did not present with any significant inflammation, bleeding, suppuration, or recession.

### Table 3

<table>
<thead>
<tr>
<th>Characteristic Location</th>
<th>Location</th>
<th>Anterior Maxilla (N = 13)</th>
<th>Posterior Maxilla (N = 27)</th>
<th>Anterior Mandible (N = 13)</th>
<th>Posterior Mandible (N = 27)</th>
<th>Total (N = 80)</th>
<th>P-Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT (Ncm)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td># missing</td>
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<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>0.31</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td></td>
<td>37.5 (8.0)</td>
<td>38.1 (7.7)</td>
<td>38 (4.5)</td>
<td>40.7 (7.7)</td>
<td>39.2 (8.0)</td>
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<tr>
<td>Min, Max</td>
<td></td>
<td>25.0, 45</td>
<td>30, 50</td>
<td>20, 50</td>
<td>20, 50</td>
<td>20, 50</td>
<td></td>
</tr>
<tr>
<td>Median (Q1, Q3)</td>
<td></td>
<td>40.0 (30.0, 45)</td>
<td>40.0 (30.0, 45)</td>
<td>35 (35.0, 37.5)</td>
<td>45 (35.0, 45)</td>
<td>40.0 (35.0, 45)</td>
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<tr>
<td>RFA (ISQ)</td>
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<td></td>
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</tr>
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<td>6</td>
<td>0</td>
<td>3</td>
<td>11</td>
<td>0.31</td>
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<tr>
<td>Mean (SD)</td>
<td></td>
<td>75 (2.9)</td>
<td>73 (7.4)</td>
<td>73.6 (15)</td>
<td>76 (4.6)</td>
<td>74.4 (7.5)</td>
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<tr>
<td>Min, Max</td>
<td></td>
<td>71, 81</td>
<td>61, 85</td>
<td>34, 85</td>
<td>66, 83</td>
<td>34, 85</td>
<td></td>
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<tr>
<td>Median (Q1, Q3)</td>
<td></td>
<td>74 (73, 76)</td>
<td>73 (67, 78)</td>
<td>77 (74, 82.5)</td>
<td>77 (73, 79)</td>
<td>76 (60.7, 71.5)</td>
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<tr>
<td>PTV</td>
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<td></td>
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<td>8</td>
<td>2</td>
<td>8</td>
<td>20</td>
<td>0.39</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td></td>
<td>−2.8 (2.2)</td>
<td>−1.8 (2.6)</td>
<td>−2.9 (3.8)</td>
<td>−3 (2.7)</td>
<td>−2.4 (2.8)</td>
<td></td>
</tr>
<tr>
<td>Min, Max</td>
<td></td>
<td>−6, 2</td>
<td>−5, 4</td>
<td>−7, 4</td>
<td>−7, 6</td>
<td>−7, 6</td>
<td></td>
</tr>
<tr>
<td>Median (Q1, Q3)</td>
<td></td>
<td>−3 (−4.5, −2)</td>
<td>−2 (−4, −0.25)</td>
<td>−4 (−6, −0.75)</td>
<td>−4 (−5, −1.5)</td>
<td>−3 (−5, −1)</td>
<td></td>
</tr>
</tbody>
</table>

*IT indicates insertion torque; RFA, resonance frequency analysis; ISQ, instability quotient; PTV, Periotest value.
†Kruskal-Wallis test.

### Table 4

<table>
<thead>
<tr>
<th>Measure</th>
<th>N</th>
<th>Correlation Coefficient</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITV and ISQ</td>
<td>64</td>
<td>0.16</td>
<td>0.20</td>
</tr>
<tr>
<td>ITV and PTV</td>
<td>56</td>
<td>−0.01</td>
<td>0.94</td>
</tr>
<tr>
<td>ISQ and PTV</td>
<td>62</td>
<td>−0.33</td>
<td>&lt;0.01†</td>
</tr>
</tbody>
</table>

*ITV indicates insertion torque value; ISQ, instability quotient; PTV, Periotest value.
†Significant correlation between ISQ and PTV.
**DISCUSSION**

Bone quality is considered to be a very important factor for implant success. Surprisingly, it did not appear to influence outcomes in this cohort of patients, regardless of the type of bone into which the implants were placed. Most likely this is related to several additional factors; among these are: understanding how to optimize bone quality, precise placement, preplanned matching of implant design and drill sequence with bone quality, and enhanced primary stability.

In 1985, Lekholm et al. classified bone quality into types I through IV. In 1988, Schnitman et al. using the freehand insertion technique, found that the success of osseointegration varied in four different regions of the jaws on the basis of bone type: The survival rate for implants placed in the anterior mandible was highest (100%), followed by the anterior maxilla (94%), posterior mandible (92%), and posterior maxilla (78%) (Figure 5).

In 1990, Misch proposed a bone classification based on density, which he felt would help in guiding practitioners to understand the importance of bone density as it relates to improved implant survival. Later, others began to report results by jaw region.

In 2001, Norton and Gambel observed CT bone density in Hounsfield (HU) numbers relate to the 4 regions of the jaw. Subsequently, others reported quantitative bone density and regional differences on the basis of CT scans. It can be seen from these studies that there is general agreement that bone density varies by the location within the jaw region—the anterior mandible being the densest, followed by anterior maxilla, posterior mandible, and posterior maxilla. It is noteworthy that in this study, 34% of the implants were placed in the least dense region of the jaws (posterior maxilla), and two-thirds of these were immediately loaded and all were successful.

While CT scans are useful for viewing available bone and bone density, it is difficult to take full advantage of this information using freehand placement. However, the CAS technique goes a step further: It actually makes possible a digitally produced surgical template, which transfers all aspects of the digital planning to the patient. As a result, the clinician can take full advantage of planning software, as the implant can be placed relative to the planned restoration with maximum engagement of cortical and the densest medullary bone. Furthermore, implant macro design and drilling sequence can be preoperatively matched to bone density at the planned site. For example, Figures 6 and 7 show the implants in the maxillary posterior region, and these demonstrate how the planning can position the implant with maximal bone engagement and still deliver the optimal position for restoration. This would have been difficult or impossible using freehand placement.

For this reason, we believe CAS may be the explanation for the complete lack of failure seen in this patient population.

Primary stability is another crucial factor in achieving implant success, and many studies support that a lower initial stability relates to a higher failure rate of dental implant therapy. Freehand placement, regardless of how precisely one tries to drill, still produces an elliptical rather than perfectly round site. In this analysis, the high primary stability achieved—especially in types III

**TABLE 6**

<table>
<thead>
<tr>
<th>Plaque Index (N = 73)</th>
<th>Gingival Index (N = 73)</th>
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<tbody>
<tr>
<td>0 66 (90.4%)</td>
<td>59 (80.8%)</td>
</tr>
<tr>
<td>1 5 (6.8%)</td>
<td>14 (19.2%)</td>
</tr>
<tr>
<td>2 0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>3 2 (2.7%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

**FIGURE 5.** Influence of implantation site on implant survival. Implant survival is highest in the anterior mandible (100%), followed by the anterior maxilla (94%), posterior mandible (92%), and posterior maxilla (78%). (Modified from Schnitman et al.)
and IV bone—is based on the ability to preplan implant design (tapered or straight) and drilling sequence, and to use the digitally produced surgical template to precisely guide drills and the implant to final position.

In this cohort of patients, the CAS technique delivered a truly biologically planned implant position combined with a precise placement technique through the use of the guided stereolithic template, resulting in uncommonly high implant success.

**CONCLUSIONS**

Restoratively driven diagnosis, as well as the precise planning and placement possible with computer-assisted techniques result in high primary stability, even in areas of less dense bone. The ability to match and implant design and drill sequence with predetermined bone density gives the practitioner enhanced pretreatment information, which can lead to improved outcomes, justifying the added time and expense of the CAS technique.

**FIGURES 6 AND 7.**

**Figure 6.** Single tooth implant in maxillary 2nd premolar area. (a) The radiograph at 1-year follow-up showing excellent bone maintenance with the implant apex appearing to be in sinus. (b) Screen shot from the computer planning software showing ability to position implant to maximize bone support with apex engaging cortex between sinus and buccal plate while maintaining the relationship to prosthetically driven position.

**Figure 7.** Maxillary three-tooth restoration supported by implants in the 1st bicuspid and 1st molar region. (a) Screen shot from the computer planning software showing the 1st premolar implant placement to maximize bone density while maintaining the prosthetically driven implant position. (b) Radiograph at 1-year follow-up of 1st bicuspid implant showing excellent bone maintenance. (c) Screen shot from the computer planning software showing tilted implant to exit in 1st molar position, paralleling the anterior wall of the sinus with 13 mm implant entirely within host bone avoiding the need for a sinus graft.
REFERENCES