BACKGROUND

Primary stability is associated with the mechanical engagement of an implant with the surrounding bone after placement. It has been identified as a prerequisite to resist micro-motion and achieve osseointegration. The main factors influencing primary stability include bone quality and volume, implant geometry, and osteotomy design. A number of techniques have been developed to assess primary stability such as insertion torque (IT) and resonance frequency analyses (RFAs). However, the correlates between these techniques and initial bone-to-implant contact (BIC) have not been adequately investigated.

The aim of this study was to compare the primary stability of standard diameter implants with different macro-geometry designs. In addition, correlations between Peak (T) IT value, implant stability quotient (ISQ) obtained from RFA, and BIC ratio were investigated.

MATERIALS AND METHODS

Table 1: Implant systems tested in the study

<table>
<thead>
<tr>
<th>Implant Systems</th>
<th>Manufacturer</th>
<th>Dimensions (Ø x Length)</th>
<th>Final Drill</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3®</td>
<td>Biomet 3i LLC</td>
<td>4.0 x 13 mm</td>
<td>4 mm quad shaping</td>
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<tr>
<td>Bone Level Tapered (BLT)</td>
<td>Straumann</td>
<td>4.1 Ø x 12 mm</td>
<td>3.5 mm twist</td>
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<tr>
<td>Tapered Internal (TI)</td>
<td>Biohorizons</td>
<td>3.8 Ø x 12 mm</td>
<td>3.2 mm</td>
</tr>
<tr>
<td>OsseoSpeed™ (OS)</td>
<td>Dentaply Sirona</td>
<td>4.2 Ø x 13 mm</td>
<td>3.1/3.7 mm step</td>
</tr>
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</table>

Figure 1: Schematic drawings of (left) full, and (right) 4mm apical, engagement of implants in simulated bone (mirrors insertion in fresh extraction sockets).

Implant & Simulated Bone: Four standard diameter implant systems in n=10/implant from Zimmer Biomet, Straumann, Biohorizons and Dentaply Sirona were tested. Artificial bone blocks (Solid Form, Sawbones® Pacific Research Labs) with 30° br/ø, cone density and 50 br/ø top-layer (3mm thick) were used.

Osteotomy Preparation: The osteotomies were prepared by following the dents in bone drilling protocols from each corresponding manufacturer. In addition to full implant engagement within the osteotomies, 4mm of apical implant engagements were achieved to simulate the immediate implant insertion in fresh extraction sockets (Fig 1).

PIT and ISQ: For both full- and apical, engagements, PIT data and ISQ values from the RFA method were recorded. The ISQ measurements were performed perpendicular to the peg in 90 degree intervals for each implant.

Imaging and IBIC Measurement: Three of the fully engaged implants were cross sectioned longitudinally along the implant center plane and optical images were taken using a light microscope (WILD HEERBRUGG, Mibas Instruments). To measure the BIC ratio, the implants were evenly divided into cervical, middle and apical regions. The ratio on each region was calculated as the percentage of linear length in contact with the pre-bonded bone using imaging software.

Statistical Analysis: One-way ANOVA with Tukey’s post hoc test was performed to compare the effects of implant design on the PIT. IT, ISQ and BIC values. The Pearson correlation coefficient was calculated to identify the relationships between PIT, IT, ISQ, and BIC values. Significant differences are indicated at p < 0.05.

RESULTS & DISCUSSION

Figure 2: Comparison of PIT and ISQ values in full engagement (top) and apical engagement (bottom) scenarios. Missing data, so not share a character are statistically significant. The BLT system did not apically engage with the simulated bone. Thus no measurements were taken. Note: BLT: Bone Level Tapered; T3: Tapered Internal; OS: OsseoSpeed.

As for the PIT and ISQ values obtained by full engagement:
- The Tapered Internal implant has a peak insertion torque value of 133.77 ± 1.793Nm, followed by the T3 implant (116.69 ± 4.304Nm). Meanwhile, the OsseoSpeed implant shows a significantly lower insertion torque value (82.19 ± 6.505Nm) than other implants.
- The ISQ values of all implants are over 70 indicating a good degree of stability. To be specific, T3 (78.3 ± 0.3), Tapered Internal (79.8 ± 0.6) and OsseoSpeed (78.5 ± 1.5) implants were significantly higher ISQ values than the Bone Level Tapered (75.2 ± 0.7) implant.
- As for the PIT and ISQ values obtained by apical engagement:
  - Only T3, Tapered Internal, and OsseoSpeed implants were engaged. The OsseoSpeed implant (30.81 ± 1.404Nm) shows the highest peak insertion torque followed by T3 implant (39.39 ± 1.298Nm). The BIC engagement. Likewise, T3, Tapered Internal, and OsseoSpeed implants have ISQ values over 20.

CONCLUSIONS

- Within the limitations of the current study, as measured by PIT and ISQ, the T3 implant exhibited consistently high primary stability in both full and apical engagement scenarios. Meanwhile, Tapered Internal and OsseoSpeed implants possessed good primary stability in full engagement and apical engagement scenarios, respectively.
- The Bone Level Tapered implant showed lower primary stability in both full and apical engagements as compared to other implants.
- The T3 implant possessed high IBIC ratios throughout the whole length of the implant, which may result in its stronger resistance to micro-motion prior to the establishment of biological (secondary) stability.
- The correlation study showed insertion torque may be a better indication of engagement between implant and bone as compared to ISQ.