# Primary Stability Analysis of Different Implant Designs: A Comparative Study

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## 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.[1,2] The main factors influencing primary stability include bone quality and volume, implant geometry, and osteotomy design.[3-5] A number of techniques have been developed to assess primary stability such as insertion torque (IT) and resonance frequency analysis (RFA). However, the correlations between these techniques and initial bone-to-implant contact (IBIC) 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 IT (PIT) value, implant stability quotient (ISQ) obtained from RFA, and IBIC ratio were investigated.

## MATERIALS AND METHODS

**Table 1**: Implant systems tested in the study

| Implant Systems | Manufacturer | Dimensions (Ø x Length) | Final Drill |
|---|---|---|---|
| T3® | Biomet 3i LLC | 4.0 × 13 mm | 4 mm quad shaping |
| Bone Level Tapered (BLT) | Straumann | 4.1 × 12 mm | 3.5 mm twist |
| Tapered Internal (TI) | Biohorizons | 3.8 × 12 mm | 3.2 mm |
| OsseoSpeed™ (OS) | Dentsply Sirona | 4.2 × 13 mm | 3.1/3.7 mm step<br>3.7/4.2 mm cortical |

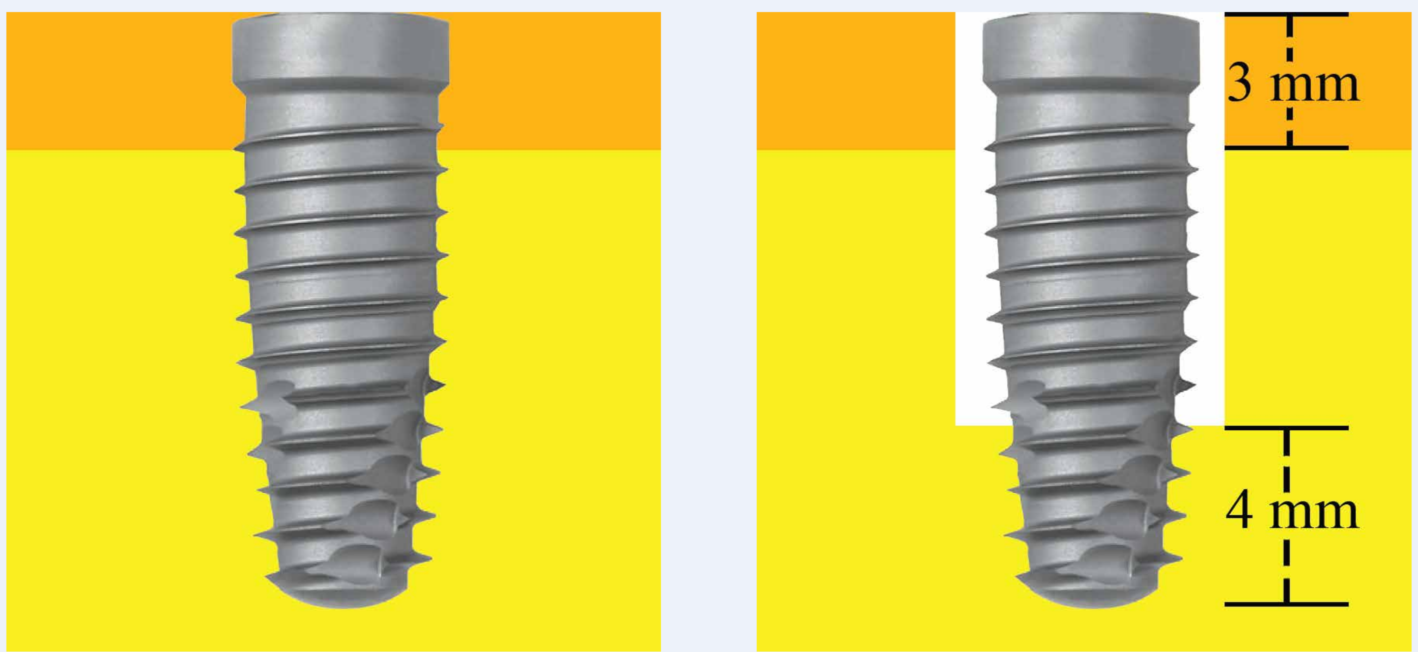


**Figure 1:** Schematic drawings of **(left)** full, and **(right)** 4mm apical, engagement of implants in simulated bone (mimicks insertion in fresh extraction sockets).

***Implant & Simulated Bone:*** Four standard diameter implant systems (n = 10/system) from Zimmer Biomet, Straumann, Biohorizons and Dentsply Sirona were tested (Table 1). Artificial bone blocks (Solid Foam, Sawbones®, Pacific Research Labs) with 30 lb/ft$^3$ core density and 50 lb/ft$^3$ top layer (3mm thick) were used.

***Osteotomy Preparation:*** The osteotomies were prepared by following the dense 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 insertions 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, Mcbain Instruments). To measure the IBIC ratio, the implants were evenly divided into cervical, middle and apical regions. The IBIC on each region was calculated as the percentage of linear length in contact with simulated bone foam using ImageJ software.

***Statistical Analysis:*** One-way ANOVA with Tukey's post hoc test was performed to compare the effects of implant design on the PIT, ISQ and IBIC values. The Pearson correlation coefficient was calculated to identify the relationships between PIT, ISQ and IBIC values. Significant differences are indicated at $p < .05$.

## RESULTS & DISCUSSION

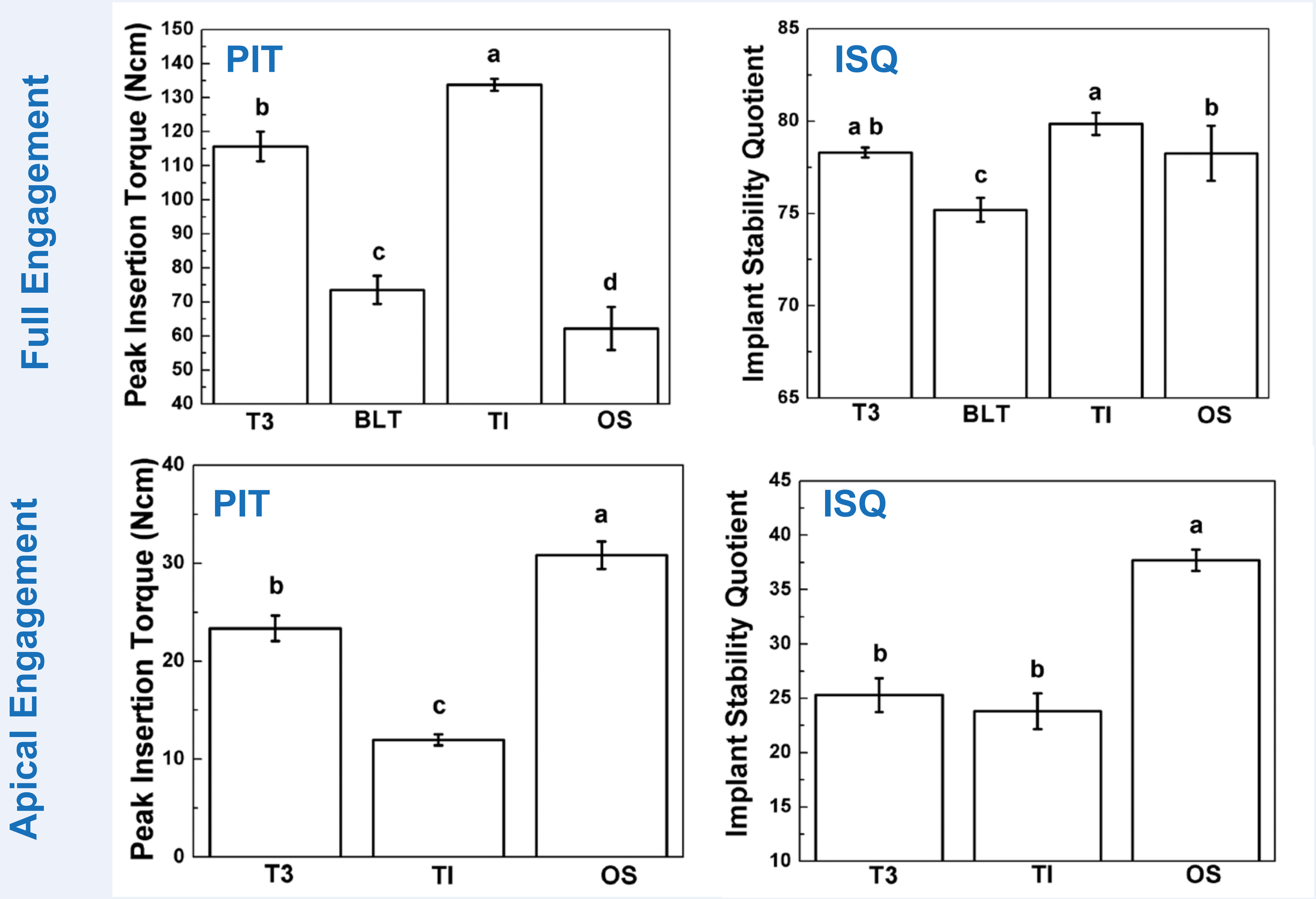


**Figure 2:** Comparison of **PIT** and **ISQ** values in **full engagement (top)** and **apical engagement (bottom)** scenarios. Means that do not share a character are statistically significant. The BLT system did not apically engage with the simulated bone, thus no measurements were taken. Note: **BLT:** Bone Level Tapered**; TI:** 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 ± 1.79Ncm, followed by the T3 implant (115.69 ± 4.30Ncm). Meanwhile, the **OsseoSpeed** implant shows a **significantly lower insertion torque** value (62.19 ± 6.30Ncm) 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** (79.9 ± 0.6) and **OsseoSpeed** (78.3 ± 1.5) implants have **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 ± 1.40Ncm) shows the highest peak insertion torque followed by T3 implant (23.36 ± 1.29Ncm) during apical engagement. Likewise, T3, Tapered Internal, and OsseoSpeed implants have ISQ values over 20.

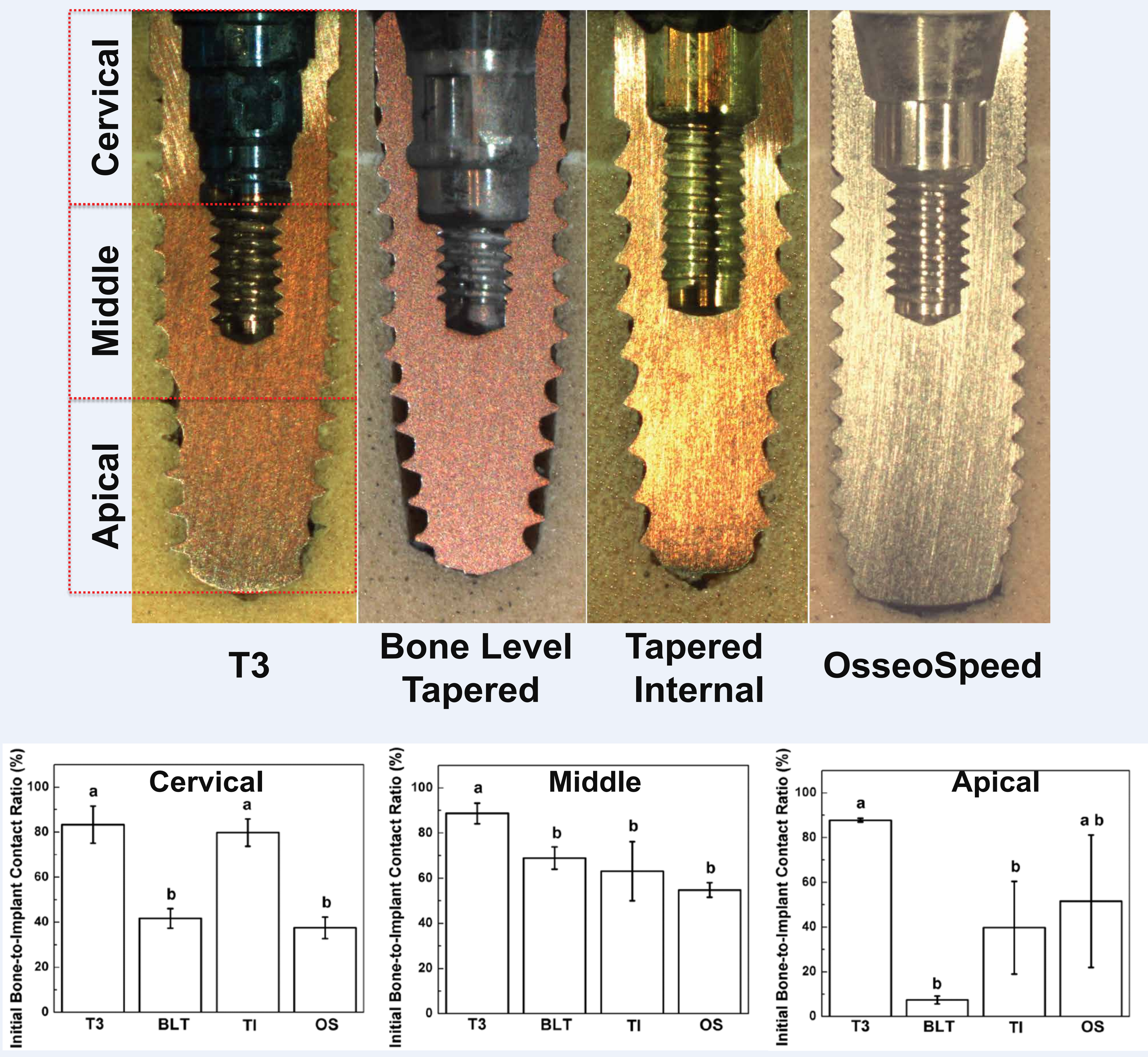


**Figure 3: (Top)** Longitudinal cross sectional images of the implant systems. **(Bottom)** IBIC measurements in the cervical, middle, and apical regions of the implants. In the apical regions, the measurements may be compromised due to the cutting flutes. Means that do not share a character are statistically significant. Note: **BLT:** Bone Level Tapered**; TI:** Tapered Internal**; OS:** OsseoSpeed.

➢As for the IBIC values obtained in the cervical, middle, and apical regions:

- The **T3** implant consistently demonstrates **significantly higher IBIC** ratios than other implants in all regions, except for Tapered Internal in the cervical and OsseoSpeed in the apical regions, where no significant differences were observed.

**Table 2**: Correlation results of PIT, ISQ, and IBIC. The IBIC from the apical region was not included due to compromised measurements from cutting flutes.

| | Pearson Correlation | | | | | |
|---|---|---|---|---|---|---|
| | ISQ | | Cervical IBIC | | Middle IBIC | |
| | Pearson (r) | Significance (p) | Pearson (r) | Significance (p) | Pearson (r) | Significance (p) |
| PIT | 0.657 | 0.343 | **0.959** | **0.041** | 0.442 | 0.558 |
| ISQ | | | 0.630 | 0.370 | -0.098 | 0.902 |

- A strong positive correlation (r = 0.657, $p$ = .343) was observed between PIT and ISQ but it was not statistically significant.
- The PIT resulted in a strong positive and statistically significant correlation (r = 0.959, $p$ = .041) with IBIC at the cervical region. A moderate positive, not statistically significant correlation (r = 0.442, $p$ =.558) between PIT and IBIC was also observed at the middle region.
- The ISQ resulted in a strong positive correlation (r = 0.630, $p$ =.370) with IBIC at the cervical region but a weak correlation (r = -0.098, $p$ = .902) with IBIC at the middle region that were not statistically significant.

## 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 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.

**REFERENCES:** 1. Meredith N, Int J Prosthodont 1998;11(5):491-501; 2. Atsumi M, *et al.* Int J Oral Maxillofac Implants 2007;22(5):743-54; 3. Stacchi C, *et al.* Clin Implant Dent Relat Res 2013;5(2):188-97; 4. Martinez H, *et al.* Clin Oral Implants Res 2001;12:423-32; 5. Moon SH, *et al.* J Periodontal Implant Sci 2010;40(5):239-43.