Original Article

# Comparison of Primary Stability of Implants Installed by Two Different Methods in D3 and D4 Bone Types: An *In Vitro* Study

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ABSTRACT

**Objective:** The purpose of the study is to assess the method of implant insertion in D3 and D4 bones and influence of insertion torque for achieving better primary implant stability. **Materials and Methods:** A total of 32 specimens (wood blocks) simulating D4 and D3 bone were grouped into 1, 2, 3, and 4. In groups 1 and 3, the implant and abutment were placed by manual method while in groups 2 and 4 by motor-driven method. The osteotomy site was prepared as per the protocol for soft bone, and implants were placed till the implant platform was in flush with the surface of the block. After achieving a standard insertion torque of 40 N.cm, pullout test was carried out with a universal testing machine and results were analyzed by one-way analysis of variance. **Results:** An intergroup comparison of peak loads revealed an overall statistically significant difference ($P < 0.0001$) with a mean of 442.638 N, maximum in group 4 and least (202.963 N) in group 1. The mean elongation break was found to be maximum in group 3 samples (81.67600%) and less in group 4 (37.15113%). Intergroup comparison of Young's modulus was statistically significant ($P < 0.0001$) with a mean value found to be minimum among group 1 samples (597.54750 MPa) and maximum in group 2 (1056.76463 MPa). An intergroup comparison of yield points was found to be maximum among group 4 samples (16.17238 MPa) and least in group 1 (5.77438 MPa). **Conclusion:** The D3 bone sample provided greater primary stability of implant than D4 bone samples, and the motor-driven implant seemed to have improved stability than that placed manually.

**KEYWORDS:** *D3 bone, D4 bone, implant insertion, primary stability, pullout force, Young's modulus*

## INTRODUCTION

Over the last few decades, the success of dental implants has shown satisfactory results in various clinical situations. They have become very important

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for durable dental rehabilitation with a reported success rate of up to 100% in mandible.[1] The success of an implant is multifactorial; some of them are bone volume and quality, surgical technique followed, type of implant used, systemic factors, and implant stability. For a successful implant, one important parameter to be considered is the clinical absence of mobility during the surgical phase; the primary stability is the crucial determining factor for the osseointegration to be effective.[2]

It is considered a prerequisite for achieving complete osseointegration, not only for the traditional two-stage approach but also in one-stage implant surgery for immediate loading of implant intended for prosthetic rehabilitation, to allow for the distribution of masticatory forces and occlusal functional loads in a state of equilibrium.[1] Implant stability depends on the quantity and quality of bone, surgical technique used, and implant characteristics. Poor bone quality and quantity has a major impact on the long-term success of an implant; however, the relationship remains unclear.[3]

One common clinical strategy followed during implantation in type IV bone to improve stability is to increase 'misfit', the undersizing of osteotomy site relative to the diameter of the implant used. By increasing this misfit, bone–implant contact (BIC) can be increased for attaining better primary stability.[4]

Various methods for assessing primary stability have been proposed, but no single method is considered precise. In medical orthopedics, pedicle screws are being used widely for treating fusion augmentation, skeletal deformities, and spinal traumas where the pullout test is the commonest method of analyzing primary stability. The pullout resistance of pedicle screws inside the vertebra depends on the mineral density and integrity of the bone, design and type of implant thread, pilot hole preparation, and insertion torque (IT).[5] Also, transpedicular screw fixation has been used extensively in treating bone instability, enhancing bony fusion, correction of bone deformities, and anatomic profile preservation.[6] Correlation between IT and pullout resistance has been a controversial topic for quite long, but a correlation was reported between a reduction in pilot hole and increased pullout resistance in mechanical assays with screws inserted in wood, polyurethane, and bovine bone.[5]

Chances of the implant getting pulled out can be encountered in situations like D4, D3, and osteoporotic patients where low-density bone type is seen.[7] In immediate loading of implants, primary stability is the key determining factor. The gold standard for determining the stability is microscopical or histological analysis, which are invasive procedures. Other methods include reverse torque analysis, resonance frequency analysis, cutting torque analysis, radiographs, pullout test, periotest, and checking clinically. There are various factors related to the pullout resistance of implant, IT being one among them. IT is determined by the equation: pullout resistance/1142 + 0.02, and the value is expressed in N.m.[5,8]

The present study was performed to evaluate and compare the primary stability of implants inserted by manual and motor-driven methods by pullout test.

## Materials and Methods

To simulate D4 and D3 bone types, wood was used as a substrate for placing the implant.[9] Two types of wood blocks were selected: D4 from *Shorea robusta* (common name sal wood) and D3 from *Pinus densiflora* (common name pine wood), where all the samples were derived from a single wood block of the stem portion stored below 19% moisture content. The samples were taken care not to exceed excessive moisture with relative humidity about 78% and temperature between 32°C and 35°C by storing them in boxes. In order to minimize the effects of temperature, moisture, and relative humidity, the whole experiment was performed with particular seasoned wood and within a short period of time.[10]

Opinions from experienced implantologists and suggestions from local timber depots were used to check the type and quality of wood. Block dimensions were 40 × 14 × 40 mm (length, width and height, respectively) to accommodate the holding plates of the universal testing machine (Dak Series 7200, Mumbai, India). A total of 32 specimens were made and divided into four groups ($n$ = 8 each) wherein groups 1 and 2 represent D4 bone type and groups 3 and 4 represent D3 bone type. For groups 1 and 3, implants were placed by hand ratcheting with an IT of 40 N.cm, while groups 2 and 4 were inserted with a low speed motor-driven handpiece of 20 rpm and with similar IT.[11]

Touareg™ S implant (Adin-India; Adin Dental Implant Systems Ltd., Afula, Isreal; Adin, MedNet GmbH, Muenster, Germany) of dimensions 10 × 4.2 mm (length and diameter) with an internal hex implant abutment connection was used for the purpose of the study. Pilot drill was used to prepare the initial osteotomy site followed by sequential drills upto a depth of 10 and 3.2 mm wide [Figure 1]. In order to maintain proper orientation and for standardizing osteotomy site, a dental parallelometer (Iso A1, Artiglio, Italy) was used for all the samples. Care was taken in placing the implant such that it merges with

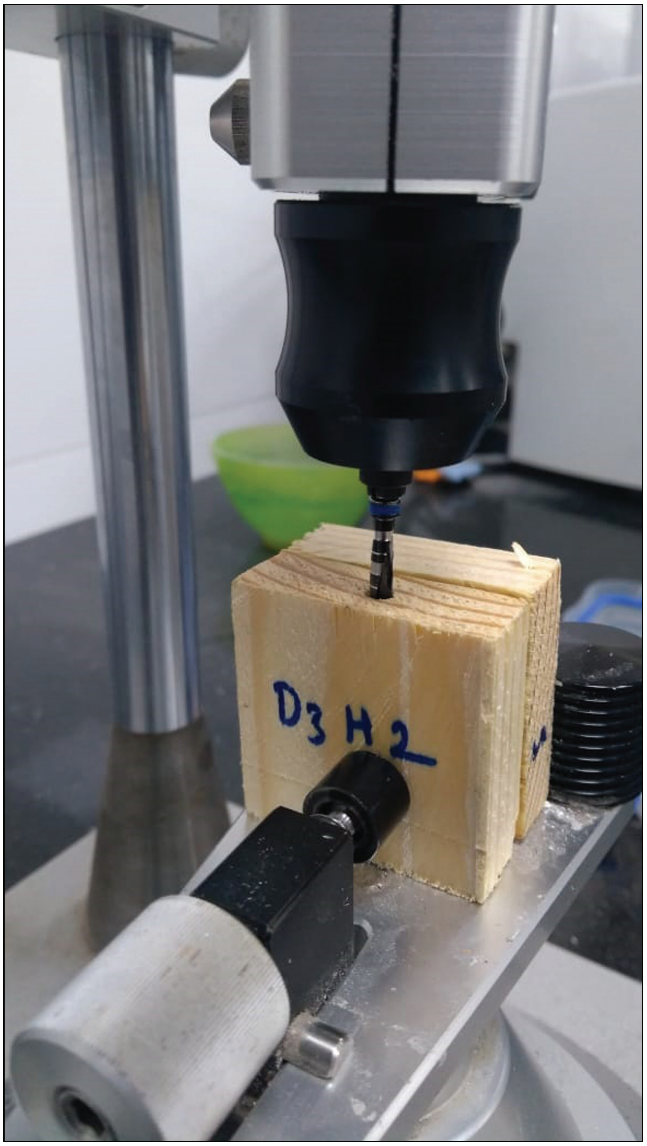


**Figure 1:** Osteotomy site preparation using sequential drills

the level of the wood. In order to perform the pullout test, an impression coping was attached to the implant so that the sample can be held between the holding plates of the universal testing machine. Implant mounts were attached to a piece adapted to a load cell of the universal testing machine to perform pullout test. An axial traction force of 10 mm/min at a load of 200 kg in the direction of the long axis of implant was applied. Data were analyzed with one-way ANOVA.

## Results

During an intergroup comparison of peak loads, overall a statistically significant difference of <0.0001 was found [Table 1]. The mean peak load was found to be maximum among group 4 samples. It was found to be significantly more than that among all the other groups. The mean peak load of groups 3 and 2 was found to be significantly high than that among group 1. No statistically significant difference could be found between groups 2 and 3.

An intergroup comparison of elongation break was done by one-way ANOVA, and overall a statistically significant difference was found [Table 2]. The mean elongation break was found to be maximum among group 3 samples and significantly more than that among groups 2 and 4. No statistically significant difference could be found between groups 1, 2 and 4.

During an intergroup comparison of Young's modulus (YM), overall a statistically significant ($P < 0.0001$) difference was found [Table 3]. The mean YM was found to be minimum among group 1 samples and significantly less than that among groups 2, 3 and 4. No statistically significant difference could be found between groups 2, 3 and 4.

**Table 1: Intergroup comparison of peak load in N.cm**

| Group | *N* | Mean | SD | 95% confidence interval for mean | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| 1 | 8 | 202.963 | 32.1695 | 176.068 | 229.857 |
| 2 | 8 | 335.838 | 59.2033 | 286.342 | 385.333 |
| 3 | 8 | 382.288 | 29.1392 | 357.926 | 406.649 |
| 4 | 8 | 442.638 | 47.9706 | 402.533 | 482.742 |
| Total | 32 | 340.931 | 98.8250 | 305.301 | 376.561 |
| *P*-value | | <0.0001, significant | | | |
| *Post hoc* pairwise comparison | | Gr 1 × Gr 2 <0.0001, significant | | | |
| | | Gr 1 × Gr 3 <0.0001, significant | | | |
| | | Gr 1 × Gr 4 <0.0001, significant | | | |
| | | Gr 2 × Gr 3 0.172, non-significant | | | |
| | | Gr 2 × Gr 4 <0.0001, significant | | | |
| | | Gr 3 × Gr 4 0.048, significant | | | |

**Table 2: Intergroup comparison of elongation break in percentages**

| Group | *N* | Mean | SD | 95% confidence interval for mean | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| 1 | 8 | 66.94038 | 19.790312 | 50.39526 | 83.48549 |
| 2 | 8 | 48.26763 | 19.914818 | 31.61842 | 64.91683 |
| 3 | 8 | 81.67600 | 33.762747 | 53.44964 | 109.9024 |
| 4 | 8 | 37.15113 | 3.901545 | 33.88935 | 40.41290 |
| Total | 32 | 58.50878 | 27.211567 | 48.69796 | 68.31960 |
| *P*-value | | 0.002, significant | | | |
| *Post hoc* pairwise comparison | | Gr 1 × Gr 2 0.345, non-significant | | | |
| | | Gr 1 × Gr 3 0.548, non-significant | | | |
| | | Gr 1 × Gr 4 0.053, non-significant | | | |
| | | Gr 2 × Gr 3 0.025, significant | | | |
| | | Gr 2 × Gr 4 0.746, non-significant | | | |
| | | Gr 3 × Gr 4 0.002, significant | | | |

**Table 3: Intergroup comparison of Young's modulus in MPa**

| Group | *N* | Mean | SD | 95% confidence interval for mean | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| 1 | 8 | 597.54750 | 19.037184 | 581.63202 | 613.46298 |
| 2 | 8 | 1056.76463 | 189.085037 | 898.68558 | 1214.84367 |
| 3 | 8 | 988.40675 | 138.081991 | 872.96732 | 1103.84618 |
| 4 | 8 | 1030.50913 | 143.094149 | 910.87942 | 1150.13883 |
| Total | 32 | 918.30700 | 230.433719 | 835.22678 | 1001.38722 |
| *P*-value | | <0.0001, significant | | | |
| *Post hoc* pairwise comparison | | Gr 1 × Gr 2 <0.0001, significant | | | |
| | | Gr 1 × Gr 3 <0.0001, significant | | | |
| | | Gr 1 × Gr 4 <0.0001, significant | | | |
| | | Gr 2 × Gr 3 0.754, non-significant | | | |
| | | Gr 2 × Gr 4 0.981, non-significant | | | |
| | | Gr 3 × Gr 4 0.927, non-significant | | | |

During an intergroup comparison of yield point (YP), overall a statistically significant difference ($P < 0.0001$) was found [Table 4]. The mean YP was found to be maximum among group 4 samples and significantly more than that among groups 3, 2 and 1.

## Discussion

Most of the studies in literature have focused on assessing implant secondary stability. However, it will be of greater importance if more studies are done on primary stability too, which has a greater impact on the process of osseointegration. A prerequisite for peri-implant bone healing is its primary stability. To meet the increased patients' and clinicians' expectations, the concept of immediate and early loading of implants has been introduced to reduce treatment time, which in turn depends mainly on primary stability.[12]

Lekholm and Zarb compared four different bone qualities using different types of wood in different regions of the jawbone. Greater concern is needed from the clinician when there is compromised bone quality during implantation. Misch identified and described those bone density areas into four groups in all the jaw regions.[9,13]

The purpose of this study was to evaluate the best method for obtaining implant primary stability in compromised bone. Because of the difficulty in collecting homogeneous human bone samples, wood was used as substrate, which has similar mechanical properties mimicking the human bone and for standardizing the test samples.[6,12,14,15]

The impact of mechanical loading and load transmission is obvious that micromotion between the bone and implant would compromise the process of osseointegration. However, in case of an efficient force transfer between the implant and surrounding tissues, mechanical loading might even stimulate peri-implant bone formation and, therefore, osseointegration. Experimental studies had shown that interfacial micromotion would compromise the establishment of implant osseointegration. So, in order to verify the bone–implant integration, the pullout test was performed in

**Table 4: Intergroup comparison of yield point in MPa**

| Group | *N* | Mean | SD | 95% confidence interval for mean | |
|---|---|---|---|---|---|
| | | | | Lower bound | Upper bound |
| 1 | 8 | 5.77438 | 1.226659 | 4.74886 | 6.79989 |
| 2 | 8 | 7.86150 | .811579 | 7.18300 | 8.54000 |
| 3 | 8 | 11.77663 | .238251 | 11.57744 | 11.97581 |
| 4 | 8 | 16.17238 | 1.964174 | 14.53028 | 17.81447 |
| Total | 32 | 10.39622 | 4.200586 | 8.88175 | 11.91069 |
| *P*-value | | <0.0001, significant | | | |
| *Post hoc* pairwise comparison | | Gr 1 × Gr 2 0.011, significant<br>Gr 1 × Gr 3 <0.0001, significant<br>Gr 1 × Gr 4 <0.0001, significant<br>Gr 2 × Gr 3 <0.0001, significant<br>Gr 2 × Gr 4 <0.0001, significant<br>Gr 3 × Gr 4 <0.0001, significant | | | |

the present study to determine the primary stability of implants clinically and also to investigate the healing capabilities at the bone–implant interface.[2,9]

It has been stated in the literature that the techniques used for assessing the primary stability of implants clinically, though viable and useful, have limitations. The method that correlates various types of implants with its initial fixation should be analogous to the human bone for mechanical testing in the laboratory.[7] Keeping these factors in mind, wood was used as a substrate for placing implants to simulate D4 and D3 bones in our study. Due to its tactile sensitivity, homogeneity, consistency, intrinsic anisotropic properties, and characteristics similar to those of bone, wood was used as a substrate for implant placement. Similar to our study, Oliscovicz *et al.* justified using wood and noted higher IT and pullout strength compared with other materials like polyurethane Synbone and pig rib bone.[9,13]

In the present study, undersizing of the osteotomy site was done to increase implant primary stability, which was in accordance with other studies suggesting 10% of underpreparation of implant bed (in length or in diameter).[16,17]

In our study, the force required to pull out the implant from the implant bed ranged from 202.963 N for group 1 to 442.638 N in group 4 samples. Hand motor-guided implant insertion was performed, which was in agreement with the study done by Huja *et al.*, where the pullout force required was 388.3±24 N despite the fact that they used Beagle dog as the testing sample.[18]

In the present study, elongation break was in the range of 37.15113–81.67600%, in contrast with the study done by Chahine *et al.*, where it was in a range of 3–14% for the materials tested. This larger variation may be due to the disparity between samples tested.[19]

Even though various methods have been proposed to objectively evaluate primary stability, an absence of gold standard led many researchers to contribute to this area of implant dentistry. One of the widely used instruments is Periotest (Siemens AG, Germany, Bensheim), but it is not a precise tool due to its lack of ability to respond to minimal variations.[20]

IT is one of the most reliable method in determining bone quality. The evaluation of IT as a measure of primary stability is one of the commonly used methods as described by Friberg and other studies.[21] So, IT was used in the present study to analyze primary stability and to evaluate bone quality and support at the time of final seating of the implant in the implant bed. In the present study, IT was kept constant for all the tested samples, which was 40 N.cm.[5,22]

Tensile or ultimate strength is the greatest stress that may be induced on an implant at the point of fracture as a result of cyclic loading or unloading, determined by YM. In the current study, this was in the range of 597.54750–1056.76463 MPa, which was in contrast with a previous study done by Inagawa *et al.*, where it was between 13.32 and 38.15 GPa. This greater difference may be attributed to the wet murine samples being examined.[23]

Although IT has been put forward for comparing the primary stability among various implant systems, the minimum acceptable amount needed for immediate loading has not been clearly hypothecated.[22] Apart from IT, the pullout test was also used in evaluating the primary stability of dental implants. When evaluating mechanical resistance, this is the commonly used method for checking the primary stability of orthopedic implants.[14,24,25]

Physiological cyclic forces acting on dental implants in human jaws are not only restricted to axial forces. Data from literature suggest pullout strength to be a predictor of primary stability, rendering useful information about the behavior of substrate such as deformation and relative rigidity.[25] Therefore, in the current study, we used the pullout test for evaluating the primary implant stability. Yield point indicates the limit of elastic behavior and the beginning of plastic behavior on a stress–strain curve. Prior to reaching the yield point, a material will deform elastically and will return to its original shape when the stress applied is removed. Once the yield point is passed, there will be non-reversible and permanent deformation, known as plastic deformation. Among the different mechanical parameters, elastic modulus is the most important one. Elastic modulus of an implant should be similar to that of the bone to avoid a high stress concentration at the bone–implant interface during load transfer.[26] Titanium is a material of choice for fabricating dental implants. A potential problem associated with these implants due to the significant differences in the elastic moduli of titanium (110 GPa) is overloading of the jawbone (≈1–30 GPa) during mastication. In the present study, the yield point was in the range of 5.77438–16.17238 MPa. The variation may be ascribed to the fact that the sample used was not human bone.[27]

In compromised bones like D3 and D4 types, in order to reduce the risk of implant failure, the dentist should consider using a framework type to fabricate an implant-supported temporary crown that influences the fatigue survival of restoration. Moreover, acrylic restoration with a cobalt-chromium base and a framework with titanium might stay intraorally for over 3 months without any damage to the implant platform.[28]

Limitations of the study are small sample size; use of wood samples as substrate, which may not exactly replicate the behaviour of bone; *in vivo* study would have been better; use of RFA technique instead of pullout force would have been a better choice for testing the primary implant stability as the interfacial failures are solely dependent on shear stress.

## Conclusion

The force needed to pull out an implant from the receptor bed was greater for D3 bone compared to D4 bone samples, as there was a necessity to achieve an ideal IT. Motor-driven implant placement seemed to improve the primary stability than when placed manually. Further work is required to see if these results can be extracted from a clinical situation.

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### Conflict of interest

None.

### Authors contributions

Dr. Vinod Bandela – Conceived & performed experiment, Dr. Bharathi Munagapati – Designing & analysis, Dr. Jayashree Komala – Manuscript, Dr. Ram B. Basany – Materials & data collection, Dr. Santosh R. Patil – Statistics & revision, Dr. Saraswathi Kanaparthi – Performed experiment.

### Ethical policy and institutional review board statement

This project is exempted from ethical approval due to lack of human and/or animal samples. All the procedures have been performed as per the ethical guidelines laid down by Declaration of Helsinki.

### Patient declaration of consent

Not applicable.

### Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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