Primary Stability of a Conical Implant and a Hybrid, Cylindric Screw-Type Implant In Vitro

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Purpose: *The differences with respect to primary stability between 2 Camlog implants, a conical implant, and a hybrid cylindric screw-type implant, were investigated in vitro. The effect of under-dimensioned implant bed preparation was also studied for both implant designs.* ***Materials and Methods:*** *In an in vitro model the stability of different implants in fresh porcine iliac bone blocks was measured using torque moment values, the Periotest, resonance frequency analysis, and push-out testing.* ***Results:*** *The conical implant showed significantly higher primary stability than the cylindric hybrid implant using the insertion torque, Periotest, and push-out tests. For both types of implants, the torque moment values following under-dimensioned preparation were significantly better than those obtained following the standard drilling protocol (Conical: 25.00 vs 11.00 Ncm; Cylindrical: 11.75 vs 5.75 Ncm). For the cylindric implant, significantly better results following under-dimensioned implant bed preparation were observed only with the insertion torque and the pushout testing values. The mean ISQ values for all groups were between 55 and 57; no statistical differences with respect to ISQ could be found.* ***Conclusion:*** *In this in vitro model conical implants showed higher primary stability than cylindric implants. The procedure of under-dimensioned drilling seemed to increase primary stability for both types of implants; however, the effect was only observable using insertion torque. RFA and Periotest, the noninvasive, clinical methods tested, did not clearly demonstrate this difference.* Int J Oral Maxillofac Implants 2006;21:560–566

Key words: *bone condensing, conical implants, dental implants, primary stability, tapering angle of implants*

Successful implant outcome is mainly the result of primary implant stability following placement[1]; thus, implant stability is key to clinical success.[2] Optimal implant stabilization is especially essential in bone of low density.[3–5] Several modifications of surgical protocol have been described to increase primary stability. It has been suggested that the anchorage of an implant in 2 cortices enables the achievement of a higher stability in soft bone.[6,7] Under-dimensioned drilling and other bone condensing procedures have also been used to increase primary stability.[8,9] In contrast to the clinical use of these procedures, basic literature reporting a mechanical effect is rare.[10]

The choice of a macroimplant design can influence primary stability as well. Many publications have reported that standard-diameter 3.75-mm-wide implants experience high failure rates in low density bone.[2,11] Some authors have recommended that the surgeon use wider implants if the width of the alveolar crest is larger than 8 mm.[12,13] However, some investigators have reported increased bone loss with wider implants.[14,15] O'Sullivan and associates investigated several unconventional implant designs and found that these designs, in combination with the use of an undersized form drill, could lead to higher implant stability than conventional designs.[16] However, a possible difference between conical and cylindric screw designs regarding primary stability has not yet been investigated.

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One major problem is the lack of a gold standard for measuring implant stability.[4,17] Periotest has been used to measure the stability of implants, but several studies have shown that Periotest is not an ideal tool for this evaluation.[18,19] Periotest is incapable of providing sensitive responses to minor changes in the implant-bone interface.[20,21] Several other groups have proclaimed that resonance frequency analysis (RFA) is a useful tool for analyzing primary stability after placement as well as degree of stability after osseointegration.[22–26] However, interpretation of the implant stability quotient (ISQ) values is still lacking scientific background. To date no break point values exist above which high or enough primary stability for direct loading can be assumed. Moreover, the RFA values of different implant systems may not be comparable.[27,28]

A more widespread method for measuring primary stability of the implant is the technique of reporting insertion torque. This method has extensively been described by Friberg and associates.[29] Low insertion torque values may indicate low primary stability and risk of implant failure. Exceedingly high primary stability, as seen for conical implants, in high density bone may also be clinically unfavorable. Thus, the implant should not be forced into position when bone density is too high. Huge placement forces may give rise to collapse of the surrounding bone and promote implant failure. In the animal models frequently used methods for quantitative evaluation of implant-bone interface strength include mechanical tests such as push-out, pull-out, or countertorque testing.[8,17,28] The disadvantages of these methods are their invasive character and the nonphysiologic forces used.

The Camlog implant system, with its internal tube-in-tube connection to the abutment, is available in conical and less-conical cylindric hybrid screw-type macrodesigns. The aim of this study was to investigate possible differences between conical and cylindric screw-type self-tapping implants with respect to primary stability. The effect of under-dimensioned implant bed preparation was also studied for both implant designs.

MATERIALS AND METHODS

Five iliac bone blocks from fresh porcine cadavers were used for this study. From each bone specimen only the trabecular part was used. A 6-mm-thick rectangular plate with parallel sides was prepared with a water-cooled precision diamond saw (Exakt Sawing-Grinding System; Exakt, Norderstedt, Germany). The surface was cleaned by rinsing with water. Every bone plate was checked macroscopically for irregularities, and the thickness of 6 mm was verified within a range of 5.4 to 7.0 mm using a pair of precision calipers. A radiograph of each bone block was obtained to check the bone density at the planned placement site. For this purpose the specimens were positioned directly on a Lanex Medium Foil with a G film (Kodak TMAT; Kodak, Rochester, NY) and exposed 122 ms at 42 kV and 2.5 mA with a Tridoros 512 MP Siemens x-ray apparatus (Siemens, Munich, Germany). For comparison and calibration a thin titanium plate was also exposed. A paper template was prepared from a photocopy of the bone samples, which indicated the planned position of the implants in the bone block. The placement of 20 to 25 implants in randomized positions in each bone block was planned. The templates were then used to measure the radiographic bone density at the specific site of implantation using a digital densitometer (model 07-424; Fluke Biomedical, Cleveland, OH). The densitometer measurements were verified within a range of 0.63 to 1.05 g/cm^2.

Two different types of Camlog implants (Camlog, Basel, Switzerland) were used for this study (Altatec, Fig 1). One was the conical implant. This implant had a diameter of 5.0 mm and a length of 13.0 mm. The other was the less conical cylindric hybrid implant, which had a diameter of 5.0 mm and a length of 13.0 mm. Both were self-tapping implants. The placement procedure for both implant types was initiated as suggested by the manufacturer. A 2.0-mm pilot drill was used first, followed by 2.8-, 3.3-, and 3.6-mm twist drills for preparation. The drilling procedure penetrated through the 6-mm-thick bone plate. The implants were consecutively assigned to 1 of the following groups:

- **Group A:** Cylindric hybrid implant, standard procedure
- **Group B:** Cylindric hybrid implant, under-dimensioned bone preparation
- **Group C:** Conical implant, standard procedure
- **Group D:** Conical implant, under-dimensioned bone preparation

For under-dimensioned bone preparation, the last twist drill in the sequence was not used. Following the twist drill procedure, either the standard 5.0-mm drill (for the standard procedure) or the 4.3-mm form drill (for under-dimensioned bone preparation) was used. Both types of implants were placed with the Nobel Biocare drilling system (Osseocare DEC 601; Nobel Biocare, Göteborg, Sweden), which recorded the torque necessary for the placement. All implants were placed so that the crestal part of the implant was totally surrounded by bone and the polished

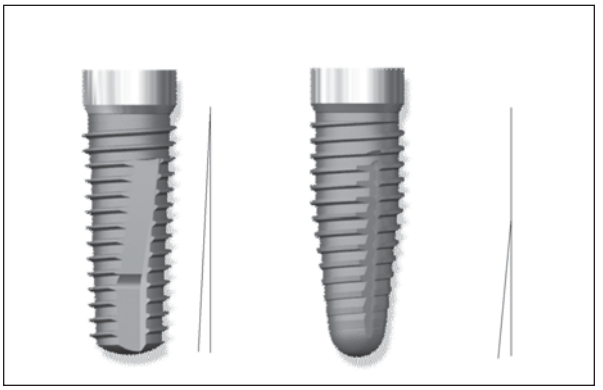

Fig 1 *(a)* The hybrid cylindric screw-type implant and *(b)* the conical implant used in this study.

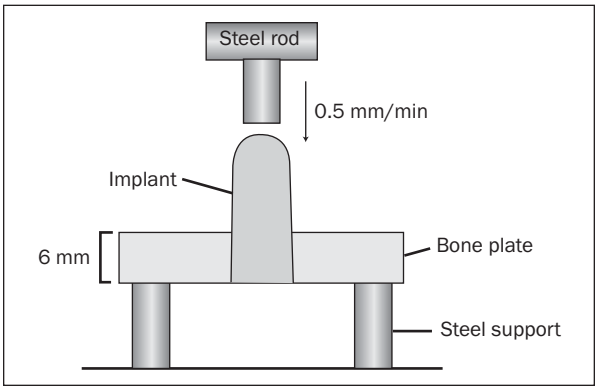

Fig 2 Experimental setup for the push-out testing.

upper part of the implant was left outside the bone. Therefore, the apical end of each implant penetrated the bone plate; about 7 mm of the implant was exposed beneath the bone plate. Subsequently, implant mobility was recorded using the Periotest (model 5950001 D 3218; Siemens). The device was hand-held at an angle of 30 degrees, and the insertion abutment was used for coupling. The procedure was repeated 3 times for each implant from different directions, and the mean values were calculated.

Next, the insertion abutment was removed from the implant, and resonance frequency analysis (RFA) was measured using the Osstell resonance frequency device (model 6.0 with connector type-F19; Osstell/Integration Diagnostics, Göteborg, Sweden). When measuring RFA, it was found that the connection between the implant and the RFA connector did not always seem to fit perfectly. In cases where the connection was unstable, the screw was refixed and the analysis redone. Finally, an abutment was fixed to the implant, and the implant-bone specimen was transferred to a Zwick UPM 1425 material testing device (Zwick, Atlanta, Georgia) to measure the axial push-out forces (Fig 2). The force was applied to the apical end of the implant in an axial direction, imitating a continuous pull-out mode. To avoid a possible influence of differences between the bone blocks, a "normalized push-out force value" was calculated for each group by dividing the individual push-out force value by the mean of the respective bone sample.

SPSS 10.0 software (SPSS, Chicago, IL) was used for the descriptive statistical analysis. Mean values and standard deviation of the different variables were calculated, and box plots were drawn to visualize the distribution of the values. The Mann-Whitney test was used to check for significant group differences. $P < .05$ was considered statistically significant.

RESULTS

Results of the insertion torque measurements are given in Fig 3 as a box plot. After standard bone preparation, the torque values of the conical implants were significantly higher than those of the hybrid cylindric implants, with mean values of 11.00 Ncm versus 5.75 Ncm, respectively ($P < .001$). For the conical implant, the torque moment values following under-dimensioned preparation were significantly higher than those following the standard drilling protocol, with mean values of 25.00 versus 11.00 Ncm ($P < .05$). For the hybrid cylindric implant, the torque moment values following under-dimensioned preparation were also significantly higher (11.75 versus 5.75 Ncm; $P < .05$); however, a much narrower distribution was seen for this implant type. So for both types of implants, there was a statistically significant difference between the standard preparation group and the respective under-dimensioned preparation group.

The mean Periotest values are given in Fig 4 as a box plot. The mean Periotest values of the conical implant were significantly lower than those of the hybrid cylindric implant (10.5 versus 13.0; $P < .05$). For the conical implant, the mean Periotest values with the different surgical protocols were 8.2 (standard) and 10.5 (under-dimensioned). The difference between the 2 procedures was not statistically significant. For the hybrid cylindric implant the Periotest values following under-dimensioned preparation were significantly lower than those obtained following the standard procedure, with mean values of 9.2 versus 13.0, respectively ($P < .05$).

The ISQ values of the different groups are given in Fig 5. Median ISQ values ranged from 55 to 57. No statistically significant difference was found between

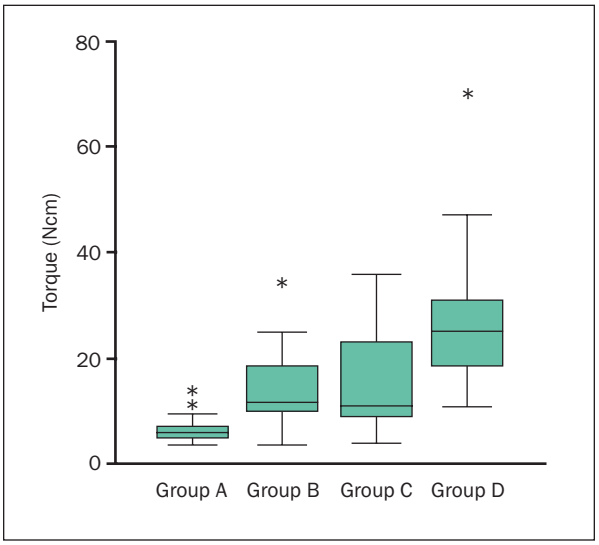

Fig 3 Torque moment values following standard and under-dimensioned drilling.

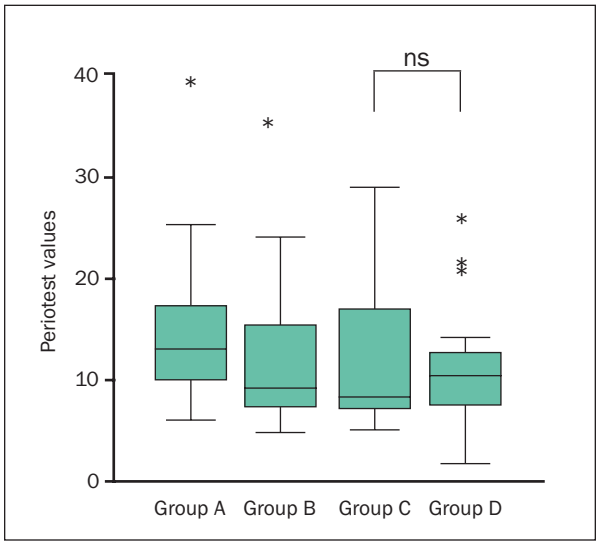

Fig 4 Periotest values following standard and under-dimensioned drilling.

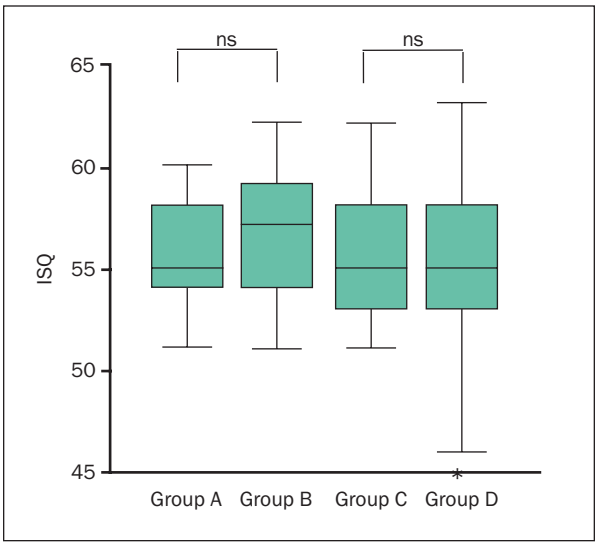

Fig 5 ISQ values following standard and under-dimensioned drilling.

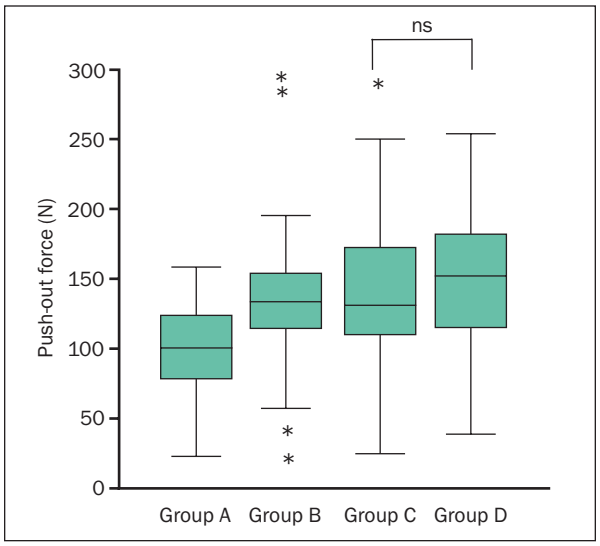

Fig 6 Push-out force values following standard and under-dimensioned drilling.

the standard and modified surgical protocols for either type of implant; furthermore, no statistically significant difference was found between the 2 types of implants. It should be noted that the values showed a wide scattering, with minimal values of 45 and maximal values of 63.

Data from the push-out testing of conical and hybrid cylindric implants following standard and under-dimensioned bone preparation are presented in Fig 6. All the samples showed high values, with ample distribution. The values ranged from 22 N to 229 N. The conical implant had significantly higher values than the hybrid cylindric implant, with mean values of 130 versus 101 N ($P < .01$). For the conical implant the mean push-out forces were 130 N and 152 N for groups C and D, respectively. This difference was not statistically significant. However, for the hybrid cylindric implant the push-out force values following under-dimensioned preparation were significantly higher, with mean values of 101 N versus 133 N ($P < .05$). Thus, there was a statistically significant difference for only the hybrid cylindric implant.

The normalized push-out force values are shown in Fig 7. For the conical implant the normalized push-out forces were 0.90 and 1.14 for the standard and under-dimensioned bone preparation prcedures,

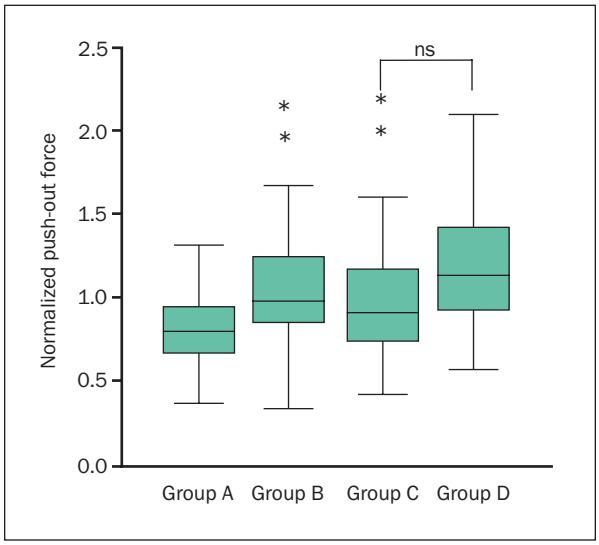

Fig 7 Normalized push-out force values following standard and under-dimensioned drilling.

Table 1 Correlation of the Different Clinical Outcome Variables (ISQ, Periotest, Torque Moment) with the Push-out Test

Implants/ methods	Pearson's correlation	Significance
Cylindric		
Push-out test versus RFA	ns	.073
Push-out test versus Periotest	0.576	.01
Push-out test versus torque moment	0.571	.01
Conical		
Push-out test versus RFA	ns	.097
Push-out test versus Periotest	0.499	.01
Push-out test versus torque moment	0.466	.01

ns = nonsignificant.

respectively. This difference was not statistically significant. For the hybrid cylindric implant the normalized push-out force values after under-dimensioned preparation were significantly lower, with mean values of 0.80 versus 0.97 ($P < .05$). Table 1 shows the correlations between the different clinical outcome variables (ISQ, Periotest, torque moment) with the push-out test for hybrid cylindric implants, and conical implants. For both implant types, significant correlations to push-out testing were found only for Periotest and torque moment. RFA did not show a correlation with the push-out test.

DISCUSSION

The axial primary stability of conical and cylindric implants were compared to each other in an in vitro model, and the results obtained using standard and under-dimensioned bone preparations were evaluated. The mechanical testing methods, ie, torque moment values, Periotest values, and push-out testing, indicated the highest stability for the conical implant following standard preparation. However, the results for RFA did not agree with the other tests in this respect.

Under-dimensioned drilling increased the torque moment values for both types of implants, which could be considered a sign of higher mechanical primary stability. Examination of the push-out force values and the Periotest showed that drilling procedure significantly affected the results for the cylindric implant but not those for the conical implant. No significant differences were found between implant types or placement procedures using RFA.

Examination of the torque moment measurements showed the most significant differences; a significant difference was found between the 2 surgical protocols as well as between the 2 implant types with respect to primary stability. This effect of increased primary stability was shown previously for the Nobel Biocare Mark IV; because this implant had a customized wider implant shape, the placement site was effectively under-dimensional.[16] Bone condensing has also been demonstrated in vivo to have an effect on the initial healing phase.[30] The present work has shown that increased implant stability in vitro might also be gained by using the same implant with smaller diameter form drills, especially if cylindric implants rather than conical implants are used.

It is somewhat confusing that the effect of obviously increased implant stability could not clearly be shown with RFA. It is known from other studies that a poor correlation between RFA, Periotest, and other parameters (eg, histology or cutting resistance) exists.[25,28,31,32] The main factors clinically influencing RFA seem to be implant type,[21,22] the height of the implant above bone,[32,33] and the bone quality in the crestal part of the bone.[25]

There seems to be evidence that different RFA values can be observed in soft (D4) bone compared with normal or dense bone.[34,35] As all implants in this model showed sufficient stability, it might be possible that the RFA method was not able to detect major differences in stability. Correspondingly, to date no defined ISQ cutoff value for sufficient primary stability has yet been established. Moreover, ISQ values for different implant systems are not com-

parable. Considering the present data and those of a previous investigation,[28] the ISQ values so far do not constitute a secure base for therapeutic decisions with regard to early implant loading. Although only large differences in primary stability seem to be detectable with RFA, clinical follow-up measurements might be informative.[25,36]

More data for different implant systems are available using the Periotest.[37] In the present study the Periotest was unable to detect a difference in primary stability between the conical implant with standard site preparation versus the same implant with a modified preparation procedure. From other studies it is well recognized that the sensitivity of the device might be too low to identify minor changes in the bone-implant interface.[20,21] Therefore, the clinical use of this device to measure implant stability is still controversial.

Besides countertorque measurements, the push-out and the pull-out testing are well established for in vitro and in vitro stability testing.[17,38–40] This technique is very sensitive to modifications of technical details; therefore, values from different studies should not be directly compared.[41,42] This sensitivity might be an explanation for why significantly different push-out values were found between site preparation methods for the hybrid cylindric implant but not for the conical implant. Another explanation for this might be that the experimental setup, ie, the application of the force for the push-out testing from the apical side of the implant in an axial direction, might produce favorable results for the cylindric implant, which is loaded with an exact perpendicular shear force, whereas the conical implant instantly loses contact with the adherent bone after a short movement.

CONCLUSION

Within the limitations of this in vitro model, it can be concluded that both the conical implant design and the procedure of under-dimensioned drilling appeared to be associated with increased primary stability. This effect was more obvious when insertion torque rather than push-out testing was used as an indicator of primary stability. RFA and Periotest, the noninvasive, clinical methods tested, did not clearly demonstrate this difference. Their clinical use for documenting primary stability of implants must be further evaluated for different implant types before clinical conclusions can be drawn. Long-term in vivo data are necessary to confirm the clinical effectiveness of the use of under-dimensioned drilling to increase primary stability.

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