



# Use of Osteotomes for Implant Bed Preparation— Effect on Material Properties of Bone and Primary Implant Stability

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The aim of this study was to evaluate the efficacy of osteotomes in enhancing bone quality as compared to conventional implant bed preparation using burs. Polyurethane foam blocks differing in density (10 pcf, 20 pcf) and structure (cellular, solid) were used. Ten implant sockets were prepared in each of the materials by means of drilling and by using osteotomes. Bone quality was assessed by measuring implant insertion torque and primary implant stability (resonance frequency analysis). Additionally, a newly designed device (BoneProbe) for bone quality testing during dental implant surgery based on intraoperative compressive tests was applied. Multivariate analysis of variance with Pillai's trace was used as test statistic (level of significance:  $\alpha = 0.05$ ) and Pearson correlation coefficients were calculated for all combinations of parameters. Whereas a significant influence of bone type on all measurement results ( $P = 0$ ) could be found, the factor preparation technique only showed a significant effect on BoneProbe measurements in the cortical area ( $P = 0$ ) and on implant insertion torque ( $P = 0$ ). The interaction of bone type and preparation technique showed a significant effect on BoneProbe measurements in the trabecular area ( $P = .002$ ) and on implant insertion torque ( $P = 0$ ). Significant correlations between all parameters were found. The application of osteotomes leads to higher values for compressive testing of bone in the apical part of an osteotomy depending on the initial density of the bone. Intraoperative compressive testing appears to be sensitive enough for quantifying localized changes in bone quality.

**Key Words:** bone density, bone quality, implant stability, mechanical testing, osteotome

## INTRODUCTION

Local alveolar bone quality and quantity, geometry of the implant as well as the placement technique used have been shown to affect primary implant stability.<sup>1,2</sup> As this purely mechanical phenom-

enon of primary stability is difficult to achieve in low quality bone, modifications of the regular surgical protocol for implant placement such as undersized drilling,<sup>3</sup> the use of tapered implants,<sup>2</sup> and the use of osteotomes<sup>4-6</sup> have been suggested.

For nonablative implant bed preparation by means of osteotomes, it has been claimed that bone would be condensed and relocated both laterally and apically, thereby enhancing local bone density and consequently primary implant stability.<sup>4,7</sup>

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However, the literature available reports non-uniform findings with the use of osteotomes.<sup>8</sup> Positive effects of bone condensing with respect to bone architecture and early healing of implants have been described in human cadaver<sup>8,9</sup> and animal studies,<sup>10,11</sup> respectively.

Applying this technique in a clinical study, Gulsahi et al<sup>12</sup> found no significant improvements in bone related parameters such as bone mineral density. Even on the contrary, in two cadaver studies, greater implant stability could be achieved using conventional methods as compared to using osteotomes.<sup>13,14</sup> Based on these contradictory findings, it was the goal of this investigation to compare conventional and osteotome-based implant preparation techniques under well-controlled, in vitro conditions. A recently introduced diagnostic tool based on compressive testing of bone surrounding an implant site was used to directly evaluate possible effects on the material properties of bone in different areas of the osteotomies.

#### MATERIALS AND METHODS

##### ***BoneProbe—Measuring device for the intraoperative determination of alveolar bone quality***

A novel measurement system named BoneProbe for the direct evaluation of bone quality during dental implant surgery was developed.<sup>15,16</sup> The sensing element of the device consists of a metal cylinder with a diameter of 3.50 mm, which is divided into 6 segments and fits into a readily prepared implant socket for a regular sized implant (Straumann Standard Implant; Institut Straumann AG, Basel, Switzerland). For determining bone quality the sensor is placed in the cortical and trabecular part of an osteotomy and expanded to 3.57 mm and 3.52 mm respectively while the force needed is recorded (Figure 1).

##### ***Bone surrogate materials***

Commercially available polyurethane foam blocks (Figure 2) differing in structure and density were used as bone surrogate materials<sup>17</sup> (Sawbones Europe AB, Malmö, Sweden):

- Blocks with a solid, homogeneous structure (Solid Rigid Polyurethane Foam 10 pcf, 20 pcf)

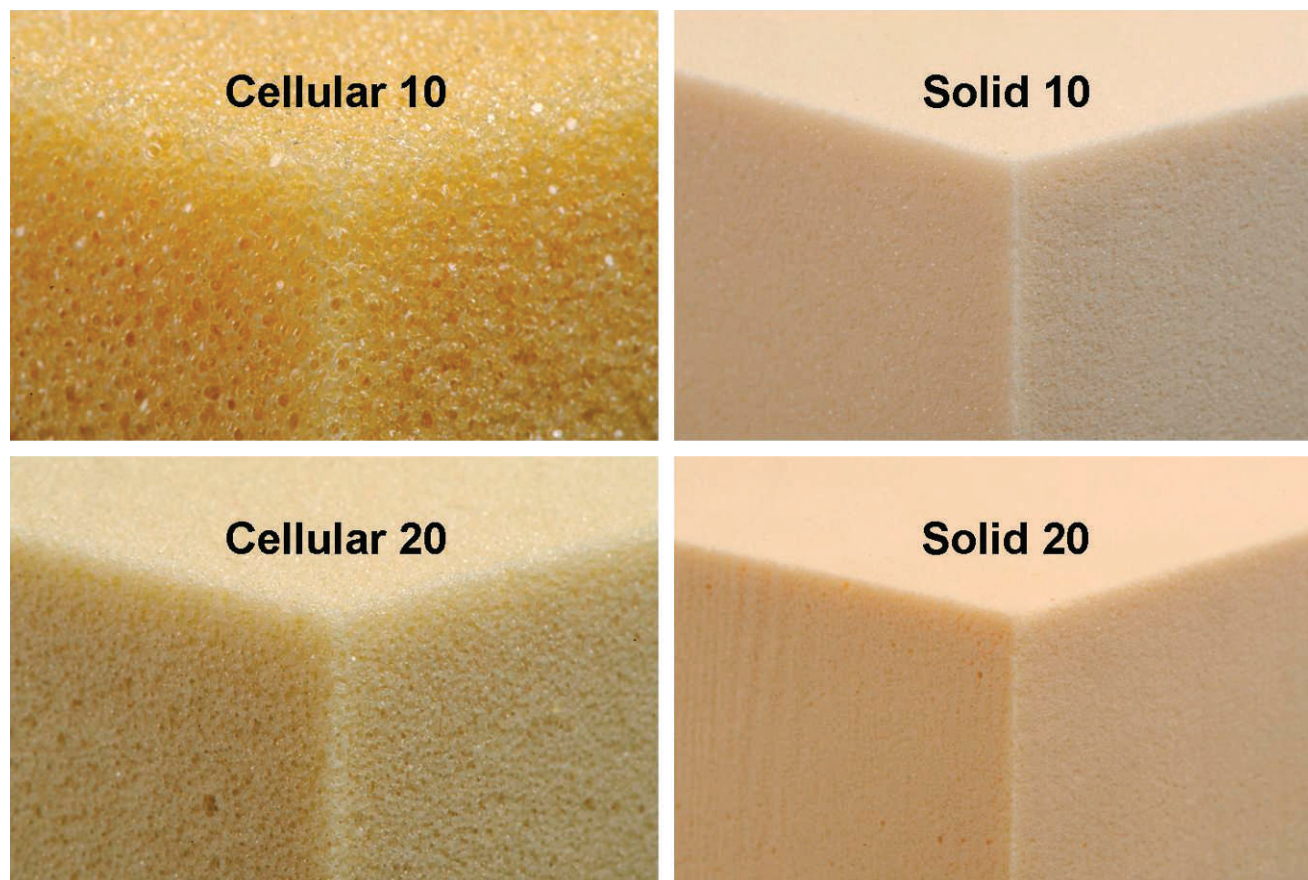


**FIGURE 1.** Sensing element of the BoneProbe consisting of a metal cylinder with a diameter of 3.5 mm, which is split into 6 segments. The sensor can be positioned in an implant socket and expanded while the actual force needed is measured.

- Blocks with a cellular structure (Cellular Rigid Polyurethane Foam 10 pcf, 20 pcf)

##### ***Conventional implant bed preparation***

Ten sockets 3.5 mm in diameter and 11 mm in length were prepared for the placement of screw-shaped cylindrical implants with a diameter of 4.1 mm and 10 mm length (Straumann Standard Implant; Institut Straumann AG) in each of the materials. The implant positions were marked with a round burr and a set of twist drills 2.2 mm, 2.8 mm and 3.5 mm in diameter was used in combination with a surgical motor (KaVo INTRASurg 1000; KaVo Dental GmbH, Biberach, Germany) to create standardized implant beds (Figure 3).



**FIGURE 2.** Polyurethane foam materials used as bone surrogate. The foam blocks either had a cellular or solid structure and densities of 10 pcf or 20 pcf.

### ***Implant bed preparation applying the osteotome technique***

For implant placement with the osteotomes technique, the implant positions (10 implants per material) were marked with a round burr, and a twist drill 2.2 mm in diameter was used to create an initial osteotomy of 11 mm in length. Bone condensing osteotomes 2.2 mm, 2.8 mm, and 3.5 mm in diameter with tapered, convex ends (Institut Straumann AG, Basel, Switzerland) were used to further prepare the implant sockets (Figure 4a). Final shaping of the osteotomies was done using a sinus lift osteotome 3.5 mm in diameter (Institut Straumann AG, Basel, Switzerland) with a parallel walled, concave end (Figure 4b).

### ***Measurements of bone quality and primary implant stability***

Upon completion of implant bed preparation, the sensor of the BoneProbe was positioned in the

socket at depths of 2 mm (cortical area) and 10 mm (trabecular area). The sensor was opened to 3.57 mm in the cortical area and 3.52 mm in the trabecular area. The forces needed to open the sensor were recorded in N. Implants were installed using a surgical motor (KaVo INTRAsurg 1000, KaVo Dental GmbH) measuring the maximum torque values needed to seat the implants.<sup>18</sup> Primary implant stability was determined by means of resonance frequency measurements (Osstell mentor, Osstell AB, Gothenburg, Sweden) and recorded as implant stability quotients (ISQ).<sup>19</sup>

### ***Statistical analysis***

Multivariate analysis of variance (MANOVA, SPSS 14.0 for Windows, SPSS Inc, Chicago, IL) was applied with preparation technique and bone type as fixed factors. Since the Box test of homogeneity of covariances revealed significant differences among groups ( $P = 0$ ), Pillai's trace, which is robust to heterogeneous variances,<sup>20,21</sup> was used



**FIGURES 3 AND 4. FIGURE 3.** Set of drills used for conventional implant bed preparation. A round burr is used to mark the implant position prior to the creation of an osteotomy using twist drills with diameters ranging from 2.2 mm to 3.5 mm. **FIGURE 4.** (a) Set of bone condensing osteotomes used for nonablative implant bed preparation following the creation of an initial osteotomy with a diameter of 2.2 mm. (b) Sinus lift osteotome with concave end, which was used for final shaping of the implant sockets.

as test statistic. The level of significance was set at  $\alpha = 0.05$ . In addition, Pearson correlation coefficients were calculated for all combinations of parameters.

### RESULTS

The mean values and standard deviations for all parameters obtained are given in Table 1. In general, the use of osteotomes led to higher measurement values in a specific material for all parameters studied with the following exceptions. In Cellular 20 material, lower values were recorded with the BoneProbe in the trabecular area as well as with the Osstell mentor device (Osstell aB) when implants were placed using osteotomes. Similarly, the use of osteotomes led to lower values with the BoneProbe in the trabecular area in Solid 20 material.

Global MANOVA with Pillai's trace revealed a significant influence of both, preparation technique and bone type on all measurement results ( $P = 0$ ).

Tests of between subject effects (Table 2) revealed a significant influence of bone type on all measurement results ( $P = 0$ ). The factor preparation technique, however, only showed a significant effect on BoneProbe measurements in the cortical area ( $P = 0$ ) and implant insertion torque ( $P = 0$ ). The interaction of bone type and preparation technique showed a significant effect on BoneProbe measurements in the trabecular area ( $P = .002$ ) and on implant insertion torque ( $P = 0$ ).

Significant correlations between all parameters were found based on Pearson correlation coefficients (Table 3).

### DISCUSSION

It could be shown that particularly in low-density bone the use of osteotomes may lead to an enhancement of bone quality and subsequently primary implant stability as assessed by resonance frequency analysis.<sup>22</sup> In materials with greater density, such an effect could not be shown consistently. On the contrary, in Cellular and Solid materials with a density of 20 pcf, even lower values have been recorded with the BoneProbe in trabecular bone. This may partially be explained by deviations in the insertion path of the osteotomes as well as in their repeated application. Supporting this interpretation, no significant effect of the preparation technique on BoneProbe readings in the trabecular area could be found. The interaction preparation technique and bone type, however, showed a significant effect for this parameter. This may be indicative for osteotomes condensing bone predominantly in the apical part of an osteotomy depending on the initial density of the bone. This was further supported by the fact that the interaction preparation technique and bone type did not show a significant effect on BoneProbe readings in the cortical part of an osteotomy whereas the factor preparation tech-

TABLE 1

Mean values and standard deviations for all parameters measured in the different polyurethane foam materials following conventional and osteotome based implant site preparation.\*

	BoneProbe Cortical [N]	BoneProbe Trabecular [N]	Osstell [ISQ]	Insertion Torque [Ncm]
Cellular 10	27.90 (10.37)	31.50 (9.43)	39.60 (9.97)	1.79 (0.70)
Cellular 10–Osteotome	43.40 (13.12)	38.60 (12.23)	43.45 (8.29)	4.68 (1.93)
Cellular 20	113.30 (13.87)	110.80 (12.11)	65.20 (4.74)	9.80 (0.58)
Cellular 20–Osteotome	122.50 (14.41)	89.00 (17.91)	64.55 (4.61)	10.70 (1.06)
Solid 10	53.40 (7.57)	40.90 (6.97)	42.50 (3.79)	2.40 (0.18)
Solid 10–Osteotome	65.20 (6.20)	44.80 (5.07)	47.55 (4.42)	4.40 (0.74)
Solid 20	139.50 (5.80)	108.20 (14.06)	64.30 (4.42)	9.54 (0.76)
Solid 20–Osteotome	142.90 (6.69)	102.70 (17.07)	65.80 (3.12)	22.40 (7.75)

\*ISQ indicates implant stability quotient.

nique alone had a significant influence on this parameter.

No effect of preparation technique and the interaction preparation technique and bone type on Osstell measurements<sup>1,19</sup> could be revealed. It therefore appears that resonance frequency measurements of implants placed in sites prepared with either of the techniques is not sensitive enough for detecting slight differences in bone density as occurring as a result of using osteotomes.

The parameter implant insertion torque<sup>18</sup> appears to be sensitive enough to detect slight differences in bone quality as all factors showed significant effects on this parameter. However, it is not possible to differentiate between effects of osteotomes in the cervical and apical part of an osteotomy as can be done using the BoneProbe as diagnostic device.

Specific limitations have to be taken into

account when interpreting the results of this study. Although it has been shown that human bone has a structure which is comparable to polymeric foams,<sup>17</sup> the use of polyurethane foam as bone surrogate material may have affected the results presented. However, these materials guarantee for standardized experimental conditions as well as simple handling characteristics.

It has been shown that measurements done using the BoneProbe correlate well with other parameters of bone quality and primary implant stability.<sup>15,16</sup> Nevertheless, this device has to be considered experimental in the current status as clinical trials proving its diagnostic value are missing. Having completed experiments in human cadaver bone,<sup>15</sup> the BoneProbe should be tested extensively in animal models and human trials in order to clarify the diagnostic value of BoneProbe measurements.

TABLE 2

Statistical analysis of measurement results based on tests of between subject effects; significant influences ( $\alpha = 0.05$ ) of the fixed factors preparation technique and bone type on measurement results (BoneProbe, Osstell mentor and insertion torque) are written in bold.

Source	Dependent Variable	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance
Preparation technique	BoneProbe cortical area	1990.013	1	1990.013	18.648	<b>0.000</b>
	BoneProbe trabecular area	332.113	1	332.113	2.093	0.152
	Osstell mentor	118.828	1	118.828	3.455	0.067
	Implant insertion torque	434.778	1	434.778	52.010	<b>0.000</b>
Bone type	BoneProbe cortical area	145 748.238	3	48 582.746	455.268	<b>0.000</b>
	BoneProbe trabecular area	82 133.938	3	27 377.979	172.570	<b>0.000</b>
	Osstell mentor	9529.759	3	3176.586	92.358	<b>0.000</b>
	Implant insertion torque	2245.317	3	748.439	89.531	<b>0.000</b>
Preparation technique * Bone type	BoneProbe cortical area	388.438	3	129.479	1.213	0.311
	BoneProbe trabecular area	2523.438	3	841.146	5.302	<b>0.002</b>
	Osstell mentor	96.159	3	32.053	0.932	0.430
	Implant insertion torque	457.930	3	152.643	18.260	<b>0.000</b>

TABLE 3

Pearson correlation coefficients describing possible correlations between all parameters studied; all correlations are significant at a level of  $\alpha = 0.05$ .\*

Correlation coefficients based on conventional implant placement				
	BoneProbe Cortical [N]	BoneProbe Trabecular [N]	Osstell [ISQ]	Insertion Torque [N cm]
BoneProbe cortical [N]		0.91	0.86	0.93
BoneProbe trabecular [N]	0.87		0.87	0.94
Osstell [ISQ]	0.86	0.74		0.88
Insertion torque [N cm]	0.76	0.75	0.67	

\*Correlation coefficients based on implants placed with the osteotome technique. ISQ indicates implant stability quotient.

Due to deviations in the diameter of the osteotomies, especially in the cervical area, the sensing element of the BoneProbe had to be opened to 3.57 mm, whereas in the apical part consistent measurements could be performed by opening the sensor to 3.52 mm. With the BoneProbe not being able to provide absolute results on the material parameters of the bone type investigated,<sup>23</sup> the force needed for opening the sensor from minimum to maximum diameter in the range of 7.5 N was neglected in the final analysis.

### CONCLUSION

Within the limitations of this in vitro study, it can be concluded that the BoneProbe is more sensitive for determining local differences in bone quality as compared to conventional techniques such as resonance frequency measurements and measurements of implant insertion torque. As could be shown based on the BoneProbe measurements, the use of osteotomes for implant bed preparation predominantly increases bone quality in the apical part of an osteotomy.

### ABBREVIATIONS

ISQ: implant stability quotient

MANOVA: multivariate analysis of variance

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