Frank Peter Strietzel
Marcus Nowak
Ingeborg Küchler
Anton Friedmann

Peri-implant alveolar bone loss with respect to bone quality after use of the osteotome technique

Results of a retrospective study

Frank Peter Strietzel, Abteilung für Oralchirurgie und Zahnärztliche Röntgenologie, Ingeborg Küchler, DRK Klinik Westend, Institut für medizinische Biometrie, Anton Friedmann, Abteilung für Parodontologie und synoptische Zahnmedizin, Zentrum für Zahnmedizin, Universitätsklinikum Charité, Medizinische Fakultät der Humboldt-Universität zu Berlin, Marcus Nowak, Private practice, Berlin, Germany

Correspondence to:
Dr. F. P. Strietzel
Universitätsklinikum Charité der Humboldt-Universität zu Berlin
Zentrum für Zahnmedizin
Abteilung für Oralchirurgie und Zahnärztliche Röntgenologie
Augustenburger Platz 1
13353 Berlin
Germany
Tel: +30 450 62609/62602
Fax: +30 450 62901
e-mail: frank.strietzel@charite.de

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Abstract: Knife-edge configurations or non space-maintaining defects of the alveolar ridge limit the indications for implant-prosthetic rehabilitations. If ridge expansion is required, bone splitting and bone spreading techniques may be applied. Summers introduced a modified approach for ridge expansion by osteotome technique. The principles of this nonablative implant bed preparation technique are lateral and apical bone relocation and condensation. The peri-implant alveolar bone loss after use of the osteotome technique was evaluated radiographically with respect to the bone quality in 22 patients with 22 implants. Differences between the alveolar crest and the implant shoulder in radiographs obtained immediately after implant insertion, after the end of unloaded healing period and after different periods of functional loading were calculated. The osteotome technique was used in bone quality classes 2 and 3, respectively, according to the Lekholm and Zarb classification. Two implants failed. Significant differences were found between the bone levels after implant insertion and at the end of the healing period as well as after functional loading ($P = 0.028$). The bone quality was significantly correlated ($r = -0.505$; $P = 0.023$) with the change of the peri-implant marginal bone height level 6 months after the implant installation. The present data indicate the importance of bone quality evaluation before application of the osteotome technique.

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Alveolar atrophy of height and width or crestal defects with an insufficient amount of bone may limit the use of endosseous implants. New methods for conditioning the planned implant site by means of bone regeneration guided by membranes or local alveolar ridge expansion allow implantations in previously unfavourable anatomic conditions. Therefore, 'backwards planning' of the implant-prosthetic rehabilitation seems to be a possible as well as predictable procedure (Garber & Belser 1995).

The alveolar ridge revealing a knife-edge morphology or non space-maintaining defects, usually requires a local alveolar ridge expansion procedure. In such situations the ridge may be expanded by splitting (Engelke et al. 1997) or spreading (Nentwig 1996; Renner et al. 1996) of the bone, resulting in a sufficient width for implant bed preparation. Summers (1994b) modified this procedure by developing a special osteotome technique and a set of instruments. The osteotome set consists of matched and tapered hand instruments which create implant sites by widening the ridge and condensing the bone in lateral and apical directions.

Different studies have focussed on the prognosis of implants that were inserted by bone splitting or bone spreading technique (Renner et al. 1996; Engelke et al. 1997). Only a few investigations have been published on the prognosis of implants inserted by osteotome procedure (Summers

1994a) or case reports (Nocini et al. 2000). The 'corticalization' of the implant site might be advantageous for the primary stability of implants in rather cancellous bone of quality class 3 or 4 according to Lekholm & Zarb (1985).

Estimation of peri-implant horizontal and vertical bone loss is an important parameter for evaluation and prognosis of implant success (Albrektsson & Zarb 1993; Roos et al. 1997).

The aim of the present clinical retrospective study was to evaluate bone loss around implants inserted by the osteotome technique, taking into consideration the bone quality at the site of implantation, and to establish more precise criteria for indications of this technique.

Material and methods

The total number of patients was 22 (12 women and 10 men) with 22 implants inserted. The distribution of age, gender, location of implant sites, the number and types of implants inserted are summarized in Table 1.

Osteotome technique was required for ridge expansion due to local alveolar non space-maintaining ridge defects and knife-edge ridge configurations at the planned implant site caused by traumatic tooth removal, loss of teeth following progressive periodontitis and repeated but unsuccessful apicoectomies.

Twenty implants were inserted under local anaesthesia (Ultracain DS forte®, Aventis, Frankfurt/Main, Germany) and two patients were treated in general anaesthesia. After full thickness flap preparation and prior to the use of the osteotome technique the bone quality was clinically determined using a pilot twist drill 2 mm in diameter. The bone quality was determined according to the classification of Lekholm & Zarb 1985). To achieve more reproducibility in the determination of the bone quality classes we modified the classification defined by Lekholm & Zarb (1985) by assigning cancellous bone surrounded by a thin cortical layer as class 3. Following the classification by Lekholm & Zarb (1985) we characterized dense cancellous bone surrounded by a thin cortical layer as class 3 as well.

After the pilot drilling, the implant bed preparation was continued with osteotomes (Osteotome Kit®, 3i Implant Innovations, West Palm Beach, FL, USA or Frialit-2® Bone Condenser® Kit, Friadent, Mannheim, Germany – applied for Frialit-2 implants only). Due to the tapered shape of the osteotomes, a slow expansion of the site by continuous use of osteotomes of different size was possible. If bone quality class 2 was diagnosed (higher degree of resistance while drilling or inserting the osteotome) the ridge was allowed to spread for 1 min with the osteotome left in place. The procedure was repeated with the next size osteotome. Insertion and removal of osteotomes was performed in a straight path with light malleting. After the final diameter of the implant bed was established, the implant was inserted. Primary wound closure was achieved after mobilisation of the full-thickness flap. Sutures were removed after 7–10 days. Second stage surgery was performed after 6 months of unloaded submerged healing. The ITI implants were left unloaded in a transmucosal manner during the same period of time.

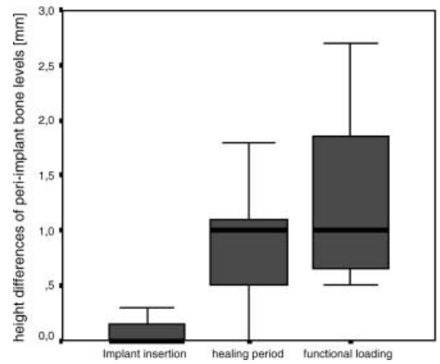

Fig. 1. Box plots of the height differences of peri-implant bone levels after implant insertion, the end of unloaded healing period and after functional loading, corresponding to Table 1.

The post-operative radiographs taken immediately after implant insertion, after second stage surgery or at the end of non-submerged unloaded healing period (ITI implants), respectively, as well as those obtained after different periods of functional loading were scanned (Friacom®, Friadent) or digitalized (Praxisarchiv®, Compudent, Koblenz, Germany). Non-standardized dental films as well as panoramic radiographs were evaluated. The radio-opaque implant the length and diameter of which was noted in the surgical protocol, was used as measuring reference. The implant shoulder and the alveolar crest were used as reference points. The length of the transmucosal conical smooth portion of the ITI implants (2.8 mm) was subtracted from the distance between the implant shoulder and the crestal bone level. Measurements of the distance between two reference points were performed at mesial and distal aspects digitally three times per implant and radiograph, and the mean values were calculated and recorded for each implant. The normal distribution of the data was tested (Kolmogorov–Smirnov test and Q-Q-plots) and statistical analysis for determination of differences in distances between reference points measured after implant insertion, the healing period and a period of functional loading were performed by the Friedman test. Wilcoxon matched pairs signed rank test for estimation of differences concerning bone height levels and Mann–Whitney test for estimation of differences of bone height levels with respect to the bone quality classes and implant

Table 1 **Distribution of age and gender, implants and implant sites (n = 22)**

Age		
Median		49 years (range 20–67 years)
Gender		
Women	12	
Men	10	
Implant types		
Osseotite® (3i Implant Innovations)	9	
Frialit-2® (Friadent)	8	
Tiolox® (Dentaurum)	2	
ITI® (Straumann)	3I	

Implant site/frequency											
16	15	14	13	12	11	21	22	23	24	25	26
1	1	2		5	3	1	1		4	4	

types were applied due to the small sample size after performing Bonferroni's α-adjustment. The correlation between the classification of bone quality and the changes of the crest levels was evaluated calculating Spearman's correlation coefficient. To evaluate influences of the different implant designs at the neck portion, data of Tiolox implants ($n=2$) as well as ITI implants ($n=3$) were excluded due to small sample sizes. A stratified cross table analysis with respect to the implant type was then performed.

For all statistical calculations the SPSS 10.0 software (SPSS Inc., Chicago, IL, USA) was used.

Results

Data of 22 implants inserted with the osteotome technique in 22 patients were evaluated in this study. The differences between the peri-implant limbus alveolaris and the implant shoulder were calculated including data of 22 implants after insertion and 20 implants after unloaded healing period of 6 months. Peri-implant alveolar bone loss was evaluated in 12 implants after different periods of functional loading (median value 6 months, minimum 3 months, maximum 12 months). Eight patients dropped out. These patients were referred for surgical implant installation only and were not available for follow up, whereas prosthetic treatment was performed at the residential dentist's.

Two implants failed during the unloaded healing period. Both were inserted into bone quality class 1. One of these implant sites had been first assigned to class 2 due to the pilot drilling. In three cases the labial cortical plate fractured during osteotomy in class 2 bone. After application of guided bone regeneration technique covering the fractured bone chips with a nonresorbable membrane (Gore Tex Augmentation Material®, 3i Implant Innovations), these implants osseointegrated without any complications. No significant differences were found between the peri-implant alveolar ridge height level with special respect to the implant types Osseotite and Frialit-2 after an unloaded healing period of 6 months (Mann–Whitney test, $P=1.000$) and after prosthetic loading ($P=0.829$). The stratified cross table analysis revealed no influence of the different implant designs at the neck portion (χ^2-test, $P=0.118$).

The distribution of implant sites revealed an over-representation of the right anterior ($n=8$) and left posterior region ($n=8$). There were no differences found between the distributions of frequencies of bone quality classes 2 and 3 with respect to the anterior and posterior implant region (χ^2-test, $P=0.457$).

Table 2 shows the median values of the differences of peri-implant bone levels immediately after implant insertion, both at the second stage surgery and at the end of the unloaded period and after functional loading (in bold). The differences in peri-implant bone levels after second stage surgery as well as at the end of the unloaded healing period and after functional loading showed a normal distribution. A significant difference between the bone height levels after implant insertion, at the second stage surgery and at the end of the unloaded period and after functional loading, was calculated (Friedman test, $P<0.0005$, $n=12$).

There was a significant difference between the peri-implant bone level after implant installation, the second stage surgery and the end of the unloaded period, respectively (Wilcoxon test, $P<0.0005$). A significant difference was calculated between the bone levels after implant insertion and the period of functional prosthetic loading (Wilcoxon test, $P=0.005$). Also, there was a significant difference in bone levels after the second stage surgery, the end of the unloaded period and the period of functional prosthetic loading (Wilcoxon test, $P=0.011$).

Peri-implant bone levels at the second stage surgery or at the end of unloaded healing period revealed significant differences regarding the bone quality classes 2 and 3 (Mann–Whitney test, $P=0.028$) so that a correlation between these parameters was concluded. A significant Spearman correlation coefficient ($r=-0.505$, $P=0.023$) could be calculated for the bone level differences at the second stage surgery as well as after the unloaded period and the bone quality classes 2 and 3.

Discussion

Implant site preparation by alveolar expansion procedures has been shown to be successful for implant integration (Summers 1994a; Renner et al. 1996; De Wijs & Cune 1997; Engelke et al. 1997) and allowed ridge expansion and implant installation during a single stage procedure.

The osteotome technique helps to recontour the alveolar ridge in the labial aspect, thus improving the aesthetic result of the reconstruction, especially in the maxillary incisor region. The osteotome procedure can be used anywhere in the maxilla, if ridge expansion as well as condensation of spongious bone of reduced density is required for improvement of the primary stability of the implant.

Due to the more retentive surface and so insured primary stability, we favoured screw type implants in regions that underwent ridge expansion procedure. Otherwise, the installation of self-tapping screw implants into sites after bone condensing osteotome technique necessitated pretapping. When ITI screw implants were used, special attention was paid to reaching the proper insertion depth to avoid contact of the smooth transmucosal neck area with the crestal bone, which would subsequent-

***Table 2.* Median values and quartiles of height differences of peri-implant bone levels between the implant shoulder and the limbus alveolaris after implant insertion, the end of the unloaded healing period and after functional loading (in bold) and the corresponding median values and quartiles divided by bone quality classes**

	After implant insertion			After unloaded healing period of 6 months			After functional prosthetic loading		
	(n = 22)	Class 2 (n = 15)	Class 3 (n = 6)	(n = 20)	Class 2 (n = 14)	Class 3 (n = 6)	(n = 12)	Class 2 (n = 9)	Class 3 (n = 3)
Median value (mm)	0.0	0.0	0.0	0.8	1.0	0.4	1.0	1.2	0.8
25%-percentile (mm)	0.0	0.0	0.0	0.5	0.5	0.4	0.5	0.6	0.5
75%-percentile (mm)	0.4	0.3	0.6	1.4	1.8	0.8	2.0	2.2	1.0

ly cause marginal bone loss (Hämmerle et al. 1996). Alternatively, the use of cylinder implants with a rough surface could be considered.

Radiographic evaluation of the peri-implant bone, in addition to assessment of several clinical parameters, became one of prerequisites for estimation of implant success (Albrektsson et al. 1986; Albrektsson & Isidor 1993; Roos et al. 1997). Gröndahl & Lekholm (1997) showed a high predictive value of radiographs for identification of implant instability using the Brånemark system.

Bone level determination based on evaluation of radiographs lacked sufficient precision because of the methodological difficulties in obtaining standardised and reproducible radiographs, excentric beam guiding and inaccessibility of the labial and lingual or palatal aspects. These methodological limitations may result in false diagnoses and measurement errors (Brägger et al. 1998). The method of computer-assisted measurement of digitalized radiographs was associated with similar problems. The amount of distortion of the measuring scale could be determined taking into account the known length and diameter of the radio-opaque implant, thus serving as measuring reference. Several options for optimising the images in contrast and brightness made the evaluation and measuring of the radiographs easier.

The results of our investigation showed a significant difference in the distance between the implant shoulder and the marginal bone level measured immediately after implant insertion and the end of unloaded period after 6 months, with a median value of 0.8 mm. This decrease in marginal bone height of maxillary implants is comparable with results published by De Wijs & Cune (1997) on implants inserted with bone splitting technique, which revealed a peri-implant ridge height reduction ranging from 0.8 to 1.3 mm. Otherwise these rates of marginal bone loss are not much different from studies where implants have been installed conventionally (Andersson et al. 1995).

The radiographic success parameters for Brånemark fixtures were defined as an occurrence of bone loss less than 1 mm during the first year, followed by less than 0.2 mm annually thereafter (Albrektsson et al. 1986; Roos et al. 1997). The mean marginal bone loss for nonsubmerged ITI implants in the first year was 0.8 mm (Brägger et al. 1998). Concerning the bone quality in our study, implants inserted into bone quality class 2 revealed an average peri-implant alveolar ridge height reduction of 1.0 mm compared to 0.4 mm around implants inserted into bone quality class 3 after 6 months. Therefore implants investigated in our study inserted by using the osteotome technique in bone quality class 2 seem to be compromised concerning radiographic success criteria proposed by Albrektsson et al. (1986).

Although alveolar ridge expansion was achieved by osteotome technique, this kind of preparation seemed to put pressure on the crestal cortical bone layer, causing a significant peri-implant marginal bone loss. Three implant sites in patients with bone quality class 2 had to be treated with membrane guided bone regeneration after partial fracture of the labial cortical bone occurred.

Concerning bone quality classes 2 and 3, statistically significant differences in the peri-implant bone loss at both the second stage surgery and the end of unloaded period were found in our measurements. The significant correlation between the bone quality classes and the extent of peri-implant bone loss revealed that the extent of marginal peri-implant bone loss around implants inserted with osteotome technique was greater in bone of higher density class 2. The implant type and design of the neck portion was found to be not relevant for differences in peri-implant bone loss.

Although some investigations on bone quality in different regions of the maxilla have been published (Misch 1990; Ulm et al. 1995), there is a lack of objective bone quality classification for clinical use. A scale of bone density ranges obtained by computerized tomography scan was proved to be helpful as a diagostic tool in the categorization of bone quality (Norton & Gamble 2001). Otherwise, CT imaging for implant planning and placement should be limited to cases with extensive and sophisticated surgical efforts. The relatively simple and clear classifications published by Lekholm & Zarb (1985) and Misch (1993) enable the clinician to evaluate bone quality during explorative pilot drilling. However, the range of varieties of bone composition and the delicate differences between the classes would not be reflected in detail. Therefore we modified the classification of the bone quality proposed by Lekholm & Zarb (1985) as described above.

Class 2 and 3 bone quality have been found to be the most common in the anterior and posterior regions of partially edentulous maxilla, as confirmed by our study. The discrepancy to the expected bone quality may be explained by former pathological processes taking place in the implant region. Pilot drilling revealed class 2 bone quality in two cases, but using the second osteotome this was changed to be class 1. Osteotome technique was indicated in these cases for ridge expansion only. Both implants were lost during the unloaded period. Thus proper evaluation of bone quality seems to be important before applying the osteotome technique.

Class 3 and 4 bone qualities according to Lekholm & Zarb (1985) and Misch (1993) were assigned for the use of osteotomes. If an alveolar ridge expansion and no bone condensation is required and bone quality class 2 is diagnosed, alternative methods such as bone spreading with final implant bed preparation by drilling (De Wijs & Cune 1997; Engelke et al. 1997) should be considered. An extension of the indications may result in a compression of intra-osseous vessels followed by compromised osseointegration.

In cases with partial fractures of the labial cortical plate due to osteotome procedure, an uneventful healing with membrane guided bone regeneration was achieved.

There are no controlled clinical longitudinal studies available on the prognosis of implants inserted by the osteotome technique. Although the power of the results of the present investigations is limited due to the short investigation period and the small sample size, our data indicate that the use of osteotome technique should be based on the evaluation of bone quality. Further investigations including a larger number of patients and considering long-term evaluation of peri-implant alveolar bone loss are necessary to enhance the power of conclusions concerning indications of the osteotome technique.

Conclusions

The use of osteotome technique for bone condensing and alveolar ridge expansion revealed an average horizontal bone loss of 0.8 mm between the alveolar ridge level and the implant shoulder at the end of the unloaded healing period after 6 months and a bone loss of 1.0 mm after an average period of 6 months of functional loading, which is comparable to that of other techniques.

The extent of the difference in distance between the alveolar ridge level and the implant shoulder was higher in bone quality class 2 compared to bone quality class 3 according to the classification of Lekholm & Zarb (1985).

Indications for the use of osteotome technique should be considered critically with respect to the bone quality: bone quality class 1 or 2 is not suitable for this kind of implant bed preparation. Bone spreading may be applied as one alternative in these situations. The local history of the implant site should be considered in the indication for and planning of implant bed preparation by osteotome technique.

Résumé

Les configurations en lame et les lésions creuses du rebord alvéolaire limitent les indications lors de réhabilitations implantaires. Si une expansion de la crête est requise, des techniques de détachement osseux ou divisions osseuses peuvent être appliquées. Summers en 1994 a introduit une approche modifiée de l'expansion de la crête avec la technique d'ostéotomie. Les principes de cette préparation du lit de l'implant sans résection sont une transposition latérale et apicale de l'os ainsi que sa condensation. La perte osseuse alvéoaire paroïmplantaire a été évaluée radiologiquement après la technique d'ostéotomie pour la qualitée osseuse de 22 patients avec 22 implants. Les différences entre la crête alvéolaire et l'épaule de l'implant dans les radiographies obtenues immédiatement après l'insertion implantaire, après la fin de la période de guérison sans mise en charge et après différentes périodes de mise en fonction ont été calculées. La technique d'ostéotomie a été utilisée dans l'os de qualité classes 2 et 3 en accord avec la classification de Lekholm & Zarb en 1985. Deux implants ont échoués. Des différences significatives ont été trouvées entre les niveaux osseux après l'insertion implantaire et à la fin de la période de guérison ainsi qu'après la mise en fonction (p=0,028). La qualité osseuse était significativement en corrélation (r=−0,505; p=0,023) avec la variation du niveau de la hauteur osseuse marginale paroïmplantaire six mois après l'insertion de l'implant. Les données présentes indiquent l'importance de l'évaluation de la qualité osseuse avant l'application d'une technique d'ostéotomie.

Zusamenfassung

Schmale Kammkonfigurationen und einfallende Defekte im Alveolarkamm limitieren die Indikationen für eine implantatprothetische Rehabilitation. Wenn eine Expansion des Kieferkammes nötig wird, können Techniken zur Knochenspaltung und Knochenerweiterung angewendet werden. Summers (1994) stellte ein modifiziertes Verfahren zur Kammerweiterung durch die Osteotome-Technik vor. Die Prinzipien dieser nichtabtragenden Technik zur Präparation von Implantatbetten sind die laterale und apikale Knochenumsiedelung und Knochenkondensation.

Der peri-implantäre Verlust an Alveolarknochen nach dem Gebrauch der Osteotome-Technik wurde radiologisch unter Berücksichtigung der Knochenqualität bei 22 Patienten mit 22 Implantaten untersucht. Auf Röntgenbildern wurden die Distanzen zwischen dem Alveolarkamm und der Implantatschulter sofort nach dem Setzen der Implantate, am Ende der Einheilzeit ohne Belastung und nach verschieden langer funktioneller Belastung berechnet. Die Osteotome-Technik wurde bei Knochenqualitäten der Klasse 2 bzw. Klasse 3 gemäss der Klassifizierung nach Lekholm & Zarb (1985) angewendet. Zwei Implantate zeigten Misserfolge. Zwischen den Knochenniveaus nach der Implantatplazierung, am Ende der Einheilzeit und nach funktioneller Belastung konnten signifikante Unterschiede gefunden werden (p=0.028). Die Knochenqualität zeigte eine signifikante Korrelation (r=-0.505 ; p=0.023) mit der Veränderung in der marginalen Knochenhöhe 6 Monate nach der Implantation.

Die vorliegenden Daten unterstreichen die Wichtigkeit der Evaluation der Knochenqualität bevor die Osteotome-Technik angewendet wird.

Resumen

Las configuraciones en filo de cuchillo o defectos de la cresta alveolar sin mantenimiento de espacio limitan las indicaciones para rehabilitaciones implanto-protéticas. Si se necesita expansión de la cresta, se pueden aplicar técnicas de ferulización y ensanche óseo. Summers (1994) introdujo un enfoque modificado para la expansión de la cresta con una técnica de osteotomía. Los principios de esta técnica de preparación no ablativa del lecho implantario son la relocación y condensación lateral y apical del hueso.

Se evaluó radiograficamente la perdida de hueso alveolar periimplantario con respecto a la calidad ósea tras el uso de la técnica de osteotomía en 22 pacientes con 22 implantes. Se calcularon las diferencias entre la cresta alveolar y el hombro del implante en radiografías tomadas inmediatamente tras la inserción del implante, tras el fin del periodo de cicatrización y tras diferentes periodos de carga funcional. La técnica de osteotomía se usó en calidades de hueso tipo 2 y 3 de acuerdo con la clasificación de Lekholm & Zarb (1985). Dos implantes fracasaron. Se encontraron diferencias significativas entre los niveles de hueso tras la inserción del implante y al final del periodo de cicatrización al igual que tras la carga funcional (p=0.028). La calidad del hueso se correlacionó (r=-0.505; p=0.023) con el cambio del nivel de hueso marginal periimplantario 6 meses tras la instalación del implante.

Los datos presentados indican la importancia de la evaluación de la calidad de hueso antes de la aplicación de la técnica de osteotomía.

要旨

歯槽堤のナイフエッジ状あるいは空間を維持できない欠損は、インプラント補綴によるリハビリテーションの適応を制限するものである。顎堤増多が必要な場合、骨の分割や開大のテクニックを用いる可能性がある。Summers（１９９４）はオステオトームを用いた顎堤拡大術の変法を考案した。この非切削式のインプラント床形成術の原則は、側方及び根尖側への骨の位置移動と圧縮である。

オステオトーム法を使用した後のインプラント周囲歯槽骨の喪失について、患者２２名の２２本のインプラントをレントゲン像によって評価したインプラント埋入直後、非荷重の治癒期間の終了時、及び機能的荷重をかけた後のレントゲン像において歯槽頂とインプラント・ショルダーの間の差を計算した。オステオトーム法は Lekholm と Zarb の骨質分類（１９８５）のクラス２と３の骨に用いた。2 本のインプラントが失敗した。インプラント埋入後と治癒期間終了時ならびに機能的荷重後の骨レベルには有意差が認められた（ｐ＝０．０２８）。骨質は、インプラント埋入６ヶ月後のインプラント周囲の辺縁骨レベルと有意に相関していた（ｒ＝－０．５０５：ｐ＝０．０２３）。同データは、オステオトーム法を使用する前の骨質の評価が重要であることを示唆している。

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