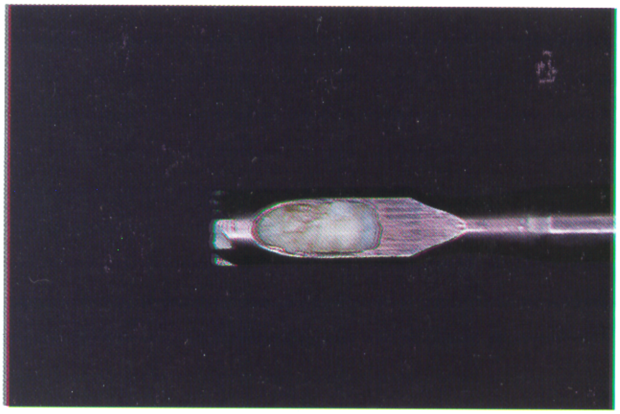


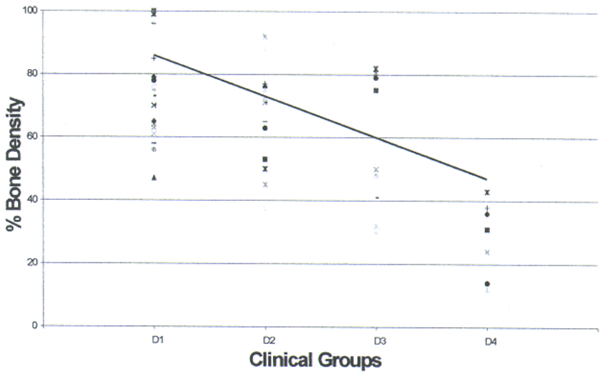
Fig. 1. The Fresissima® trephine burr used to retrieve the bone biopsies was specifically designed to create a pilot hole apt to successive implants placement.

drilling oak or maple wood, D2 is similar to white pine of spruce wood; D3 is similar to balsa wood, and D4 is similar to Styrofoam.

A new method suggests the use of electronic devices to determine the bony resistance to drilling as a measure of the bone quality (Friberg et al. 1995; Johansson & Strid 1994). Nevertheless, the bone structure varies in the jaws from site to site, and from patient to patient. The most biologically reliable system for bone structure evaluation is histomorphometric examination of bone biopsies, but it is not routinely applicable to clinical practice. Despite the large number of studies regarding the bone quality, to our knowledge, no study has been published correlating the hand clinical classification of the bone to its histomorphometric structure.

The aim of the present study was to correlate the hand-assessed clinical quality of the bone to its histomorphometric bone density.

Table. 1. Scatterplot of the individual data points, in which groups are listed on the horizontal axis and the histomorphometric values are plotted on the vertical axis and indicated as percentage of bony trabeculae over the total bone surface



Materials and methods

After having obtained the patients' informed consent, a small bone biopsy was harvested in 56 patients during oral implant surgery.

Patients, in good general health, undergoing oral implant surgery, were selected. A special trephine burr, 2 mm internal diameter and 5 mm length (Trephine Drako® N. 994RF, by Fresissima® – F.I.T. s.r.l. Torino, Italy) specifically designed for this study, was used as a pilot drill for implant bed preparation during implant placement (Fig. 1). A new drill was used for each patient in order to always have a perfect cutting ability. The bone drilling was performed under profuse saline irrigation at 800 r.p.m., in order to avoid tissue overheating. The selection of the implant site was randomized, in order to analyze the occurrence of each type of bone in the jaws. The diameter of the trephine burr was smaller than the final drill used in the surgical implant protocol. In this way, it was possible to place the implants with the correct primary stability. The bone scoring was recorded during drilling, based on the surgeon's hand-felt perception of the drilling resistance, according to Misch (1993) as D1, D2, D3 and D4 type. A recent study (Klinge et al. 1995) states that this surgical procedure does not affect the short term implant survival rate. After retrieval, each biopsy received a progressive number and the relative clinical score was registered. Successively, the biopsies were treated in a blind fashion for the histomorphometric analysis so that the histologist was not aware of the clinical score of each sample. At the end of the process of histomorphometric measurements, each sample was compared to the corresponding clinical score and the statistical analysis was performed.

Histologic processing

The retrieved bone biopsies were carefully extracted from the implant beds, rinsed in physiologic, pH 7.4, solution and fixed in 10% neutral buffered formalin.

After fixation, the specimens were dehydrated in an ascending series of alcohol rinses and embedded in Remacryl resin[1]. After polymerization 200–250 µm sections were obtained by a wafering high speed rotating blade microtome (Micromet, Remet, Bologna, Italy) and the sections were subsequently ground down to about 40–50 µm, by a grinding machine (LS2, Remet, Bologna, Italy) according to the technique of Donath &

[1] Remacryl is an experimental resin prepared in the Istituto di Microscopia Elettronica Clinica, in the Ospedale Sant'Orsola, in Bologna, Italy, by Mr Cesare Scala.

Table 2. Percentage distribution of the bone quality in the jaws, as assessed by hand drilling resistance

D1	39.2%
D2	25.1%
D3	23.2%
D4	12.5%

Breuner (1982). The histologic slides were then routinely stained with toluidine blue for light microscopic observation.

Histomorphometric and statistical analysis

Histomorphometric analysis was performed by counting, in a rectangular integrating grid eyepiece with horizontal and vertical lines, the areas occupied by the bony trabeculae over the total bone plus marrow area. These measurements were performed with a 10× objective in all the specimen's fields, by counting the intersections over the bony trabeculae. For each bone biopsy, 3 sections, measuring about 10 mm^2 each, were analyzed. Finally, the results were expressed as percentage of bony trabeculae over the total bone area. These measurements were performed on each specimen and the results were grouped into the four corresponding classes that each biopsy was assigned during drilling.

Subsequently the values were grouped in a scatterplot of the individual data points in which groups are listed on the horizontal axis and the histomorphometric values are plotted on the vertical axis (Table 1).

The Spearman's rank correlation test of significance was applied to test the hypothesis that there is a correlation between the two sets of data.

A numerical measure of the overlap observed in the scatterplot has been conveyed using the analysis of variance among groups relative to the total variance of the histomorphometric measurements.

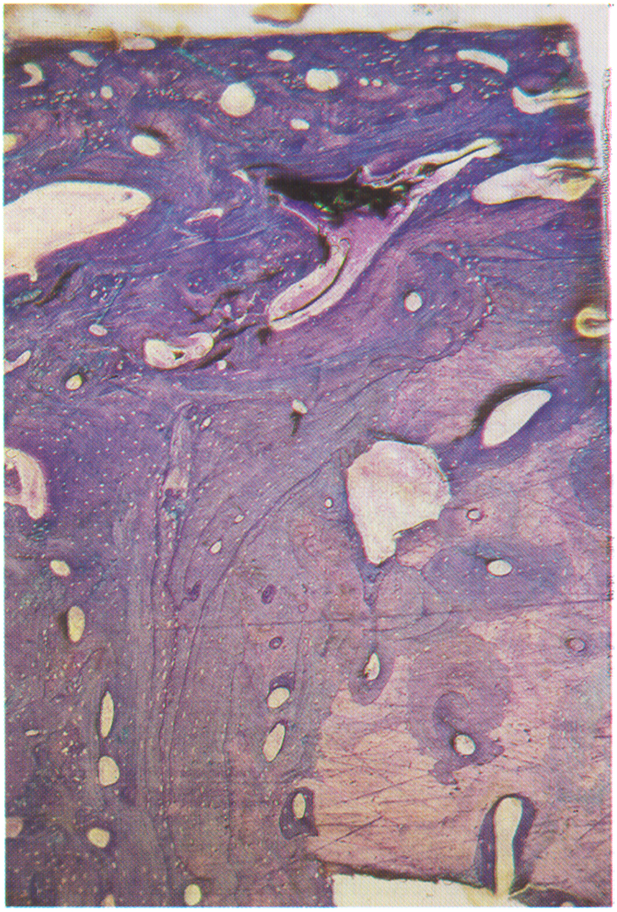


Fig. 2. Histologic micrograph of one of the analyzed biopsies pertaining to clinical class D1. (Toluidine blue – original magnification ×50; bar=0.2 mm.)

Fig. 3. Histologic micrograph of one of the analyzed biopsies pertaining to clinical class D2. (Toluidine blue – original magnification ×50; bar=0.2 mm.)

Fig. 4. Histologic micrograph of one of the analyzed biopsies pertaining to clinical class D3. (Toluidine blue – original magnification ×50; bar=0.2 mm.)

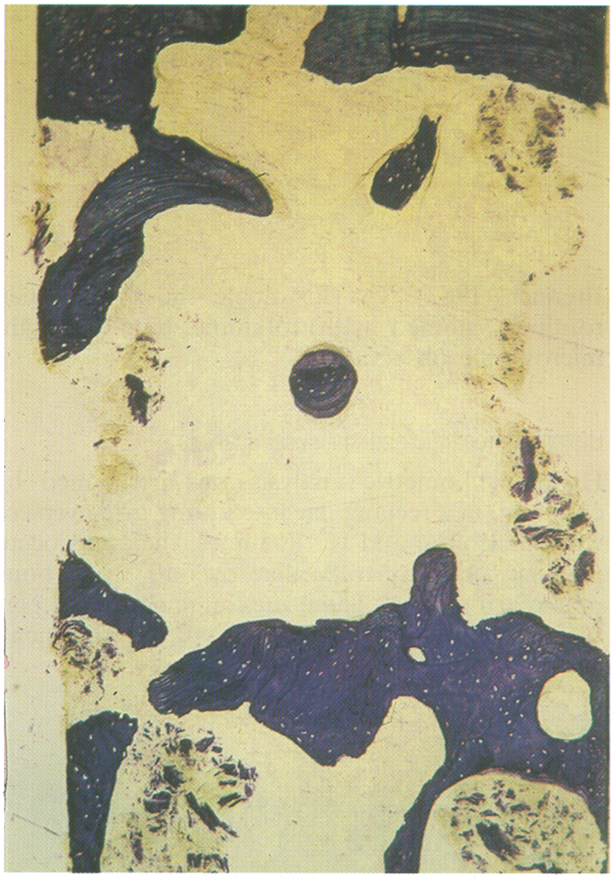


Fig. 5. Histologic micrograph of one of the analyzed biopsies pertaining to clinical class D4. (Toluidine blue – original magnification ×50; bar=0.2 mm.)

Results

The postoperative period was almost uneventful for all the treated patients. All the implanted fixtures reached osseointegration.

The distribution of the bone quality, as assessed by clinical score, is expressed in Table 2.

The bone quality was dispersed as follows: 39.2% of the analyzed sites were in D1 (Fig. 2), 25.1% were in D2 (Fig. 3), and 23.2% in D3 (Fig. 4) bone quality, while 12.5% scored D4 (Fig. 5).

Table 3. Mean histomorphometric percentage bony trabeculae area's value (±SD) of the biopsies related to their hand assessed clinical scoring

Clinical score	Mean±SD histomorphometry density
D1	76.54*±16.19
D2	66.78±15.82
D3	59.61±19.55
D4	28.28*±12.02

*Statistically significant difference from the total population.

The mean histomorphometric values, with the relative standard deviation, of the bone biopsies are listed in Table 3. These data show a progressive decrease in the mean bone density in relation to the different clinical scoring. Samples from the D1 class showed a mean bony area of 76.54±16.19 (range 47–100%). Samples from D2 showed a mean value of 66.78%±15.82 (range 37–92%). D3 specimens had a mean histomorphometric value of bony trabeculae scoring 59.61%±19.55% (range 30–82%). D4 samples had a mean value of 28.28%±12.02 (range 12–43%).

There was good agreement between the clinical density and the histomorphometric values. When comparing the mean density and the clinical score, with the Spearman's rank correlation test, a significant correlation (P=0.000; t=3.782276 with d.f.= 54) was found between the amount of bone trabeculae in the biopsy and its clinical scoring density.

The interclass correlation analysis of the variance showed that the clinical classes D1 (P=0.01) and D4 (P=0.0006) were significantly different from the total population. On the other hand, the clinical classes D2 (P=0.6) and D3 (P=0.4) were not significantly different.

Discussion

Bone density in the recipient implant site seems to be an important factor for long term success of endosseous osseointegrated implants (Engquist et al. 1988; Jaffin & Berman 1991). Misch (1990b) suggested the use of longer healing periods and progressive loading for implants placed in poor quality bone.

One of the most reliable methods for identifying bone quality is to evaluate a bone biopsy taken from the jaw bone. This procedure is reliable and safe, but not applicable to routine clinical practice (Friberg et al. 1995). Different techniques, such as various radiographic examinations, often do not allow to determine the structures of the cancellous bone portion. For this reason many surgeons rate the bone quality based on their hand-felt perception of the bone drilling resistance, during implant site preparation. In order to improve this technique, some authors (Johansson & Strid 1994) measured the bone cutting resistance by a computerized method, and this system was compared to the bone structures by Friberg et al. (1995). Nevertheless, the high costs and difficulties of such a system restrict its diffusion in clinical settings. For these reasons, we compared the hand perception of bone cutting resistance to the histological grading obtained by histomorphometric evaluation of bone biopsies. In a recent paper Klinge et al. (1995) stated that implant site preparation, by a trephine burr, is a safe method for preparing implant bed. We retrieved 56 biopsies from oral surgery sites with a trephine burr and clinically scored the bone quality according to Misch (1993).

The large range of distribution of the histomorphometric data, in each class, caused an overlapping of the adjacent classes, so that statistical tests did not give significant differences between adjacent classes D2 and D3. This fact could be explained considering that the real bone density cannot be separated in 4 different types, but there exists a continuous gradient of bone density with all the intermediate values. It is said that drilling D1 bone is like drilling oak or maple wood, D2 is similar to white pine of spruce wood; D3 is similar to balsa wood, and D4 is similar to Styrofoam (Misch 1993). Nevertheless, all the intermediate values may be encountered between these cases, and the surgeon may have some difficulty in distinguishing between the neighboring categories, except for the D1 and D4 bone. The D1 and D4 bone biopsies showed histomorphometric structures significantly different from all the other classes, demonstrating their reliable clinical differentiation. Most of the implant failures associated to jaw bone quality have been associated to the D4 bone, especially in the posterior maxilla. No report showed higher failure rates in the D1, D2 or D3 bone.

This study demonstrated that the hand-felt perception allows to distinguish, with statistically significant confidence, D4 bone from all other types, but failed to assess the intermediate level of bone density.

When the surgeon has identified the very low D4 quality bone, some concerns must be addressed. First, the patient should be aware of the lower success rate of implants placed in these areas. Further, the prosthodontist should progressively load the implants according to the Misch concepts of progressive loading (Misch 1993).

Acknowledgement

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Résumé

Cette étude a eu pour but de mettre en relation l'évaluation clinique *de manu* de la qualité osseuse à sa structure histologique quantifiée par l'évaluation histomorphométrique de la densité osseuse. De petites biopsies osseuses ont été prélevées chez 56 patients durant une chirurgie implantaire buccale et utilisées pour cette évaluation histomorphométrique. Le score osseux a été enregistré durant le forage du lit implantaire basé sur la perception manuelle de la résistance au forage. Les biopsies osseuses ont ensuite été traitées afin d'obtenir des coupes fines de l'os. Les résultats de l'analyse histomorphométrique ont été exprimés en tant que pourcentages de trabécules osseuses vis-à-vis de la zone de biopsie totale. Le test de corrélation de Spearman a été appliqué pour calculer les différences statistiques des classes de densité osseuse trouvées cliniquement et la régression linéaire a été calculée. Les échantillons D1 ont montré une densité histomorphométrique moyenne de 76,5%±16,2. Les échantillons D2 possédaient une valeur moyenne de 66,8%±15,8. Les échantillons D3 avaient une densité histomorphométrique moyenne de 59,6%±19,6%. Les D4 avaient une valeur moyenne de 28,3%±12,0. L'analyse de corrélation interclasse de la variance a montré que les classes cliniques D1 (P=0,01) et D4 (P=0,0006) étaient significativement différentes de la population. Par contre les classes D2 (P=0,6) et D3 (P=0,4) n'étaient pas significativement différentes. Cette étude a donc mis en évidence que la sensation manuelle permet de distinguer avec une confiance statistiquement significative l'os D1 et D4 mais ne peut distinguer entre les classes de qualité osseuse intermédiaires.

Zusammenfassung

Es war das Ziel dieser Untersuchung, die klinische manuelle Ermittlung der Knochenqualität mit der histologischen Struktur, welche durch eine histomorphometrische Untersuchung der Knochendichte ermittelt wurde, zu korrelieren. Während des chirurgischen Eingriffs beim Setzten von Implantaten wurden bei 56 Patienten kleine Knochenbiopsien gesammelt und für die histomorphometrischen Untersuchungen verwendet. Während des Bohrens des Implantatbetts wurden basierend auf dem manuellen Empfinden des Bohrwiderstands die Knochenbewertungen vorgenommen. Die Knochenbiopsien wurden dann zu dünnen Schliffpräparaten aufgearbeitet. Die Resultate der histomorphometrischen Analyse wurden als prozentuale Anteile der Knochentrabekel von der totalen Biopsiefläche dargestellt. Um die statistischen Unterschiede in den klinisch gemessenen Kategorien der Knochendichte zu berechnen, wurde ein Spearman's rank Korrelationstest angewendet. Zusätzlich wurde eine lineare Regressionsanalyse durchgeführt. Proben von D1 zeigten eine mittlere histomorphometrische Dichte von 76,54%±16,19. Proben von D2 zeigten einen mittleren Wert von 66,78%±15,82. Präparate von D3 wiesen eine mittlere histomorphometrische Dichte von 59,61%±19,55 auf. Proben von D4 hatten einen mittleren Wert von 28,28%±12,02. Die Korrelationsanalyse der Varianz innerhalb der Klassen zeigte, dass sich die klinisch ermittelten Klassen D1 (P=0,01) und D4 (P=0,0006) signifikant von der Population unterschieden. Andererseits zeigten die Klassen D2 (P=0,6) und D3 (P=0,4) keine signifikanten Unterschiede. Diese Untersuchung zeigte, dass es mit manuellem Gefühl möglich ist, mit statistisch signifikanter Sicherheit zwischen D1 und D4 Knochen zu unterscheiden, jedoch die Zwischenklassen der Knochenqualität nicht unterschieden werden können.

Resumen

Este estudio se realizó con la intención de correlacionar las valoraciones clínicas manuales de la calidad de hueso con la estructura histológica cuantificada por evaluación histomorfométrica de la densidad ósea. Se recogieron pequeñas biopsias de hueso en 56 pacientes durante cirugías para implantologia oral y se utilizaron para evaluación histomorfométrica. Los valores de hueso se registraron durante la perforación del lecho implantário basados en la percepción manual de la resistencia a la perforación. Las bopsias de hueso fueron posteriormente procesadas para obtener secciones finas. Los resultados del análisis histomorfométrico se expresaron en porcentaje de travéculas óseas sobre el total de área de bopsia, y el test de correlación del rango de Spearman, se aplicó para calcular las diferencias estadísticas de las clases clínicas de densidad ósea valoradas y se calculó la regresión lineal. Muestras de D1 mostraron una densidad histomorfométrica media del 76.74%±16.19. Muestras de D2 mostraron un valor medio del 66.78%±15.82. Los especímenes D3 tuvieron unos valores de densidad histomorfométrica media del 59.61%±19.55%. Las muestras D4 tuvieron un valor medio de 28.28%±12.02%. El análisis de la correlación interclase de varianza mostraron que las clases valoradas clínicamente D1 (P=0.01) y D4 (P=0.0006) fueron significativamente diferentes de la población. Por otro lado las clases D2 (P=0.6) y D3 (P=0.4) *no fueron significativamente. Este estu*dio demostró la sensibilidad manual permite distinguir con una confianza estadísticamente significativa hueso D1 y D4 pero fracasa en distinguir entre las clases intermedia de calidad ósea.

要約

本研究の目的は、手の感触による骨質の臨床的評価と骨密度の組織形態測定評価によって定量化された組織学的構造とを関連づけることであった。５６名の患者の口腔インプラント手術中に少量の骨生検標本を採集し、組織形態測定評価に用いた。インプラント床の形成中に、切削抵抗の手の感触に基づいて、骨のスコアを記録した。次に骨生検標本を取り、薄い組織切片を得るための処理をした。組織形態測定分析の結果は、全生検標本面積に対する骨稜のパーセンテージとして表現し、**Spearman's rank correlation** テストにより臨床的に評価した骨密度のクラスの統計学的差異を計算し、また直線回帰を計算した。**D1** からの標本は、組織形態測定密度は平均７６．５４％±１６．１９を示し、**D2** からの標本は平均値６６．７８％±１５．８２であった。**D3** 標本は組織形態測定密度のスコアは平均５９．６１％±１９．５５であった。**D4** 標本は、平均値２８．２８％±１２．０２であった。

変動のクラス間相関分析は臨床的に評価したクラス **D1**（ｐ＝０．０１）と **D4**（ｐ＝０．０００６）が母集団と有意に異なっている事を示した。他方 **D2**（ｐ＝０．６）と **D3**(ｐ＝０．４)は有意差ではなかった。

本研究は手の感触による判別は、**D1** と **D4** の骨の区別では統計的に有意な信頼性を示したが、中間クラスの骨質の区別には失敗したことを示した。

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