research article

COMPARING THE TIOBLAST AND OSSEOSPEED SURFACES. HISTOMORPHOMETRIC AND HISTOLOGICAL ANALYSIS IN HUMANS

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SUMMARY

Comparing the TiOblast and Osseospeed surfaces. Histomorphometric and histological analysis in humans

The aim of the present study was to compare two implant surfaces, the TiOblast (Astra Tech) surface, manufactured by blasting the surface and already present in literature and the Osseospeed (Astra Tech) surface, manufactured by blasting and treating the surface with fluoride ions and recently launched onto the market with the modified surfaces of the latest generation. This study is part of a more extensive research project whose protocol required the insertion of 10 couples of implants; thus in the present discussion partial data are being taken into consideration, with an eye at collecting more data in the future, regarding both microscopy and histomorphometric histological analysis on 5 couples of implants. The purpose of the study is to investigate how the modified surfaces of the latest generation can guarantee a greater osseointegration both from a qualitative and quantitative level compared to the surfaces presently used and that they may represent the first example of "bioactivity", that is, an active interaction with the processes of new bone formation and tissue healing.

Key words: sandblasted surface, fluoride, histology, histomorphometry, microthreads, macrothreads.

RIASSUNTO

Comparazione tra la superficie TiOblast e la superficie Osseospeed. Analisi istologica ed istomorfometrica nell'umano

Il presente studio è finalizzato alla comparazione tra due superfici implantari, la superficie *TiOblast* (Astra Tech) ottenuta per sabbiatura e già presente in letteratura e la superficie *Osseospeed* (Astra Tech), ottenuta per sabbiatura ed implementazione con fluoro in forma ionica, di recente introduzione sul mercato nell'ambito delle superfici modificate di ultima generazione. Questo studio è parte di un progetto di ricerca più ampio, il cui protocollo ha previsto l'inserimento di 10 coppie di impianti; pertanto nella presente discussione vengono presi in considerazione dati parziali, che ci riserviamo di ampliare, riguardanti l'analisi istologica al microscopio ottico ed istomorfometrica su 5 coppie di impianti. L'obiettivo della ricerca è quello di verificare che le superfici modificate di nuova generazione possano garantire un'osteointegrazione qualitativamente e quantitativamente maggiore rispetto alle superfici attualmente in uso e che dunque possano rappresentare un primo esempio di "bioattività", cioè di interazione attiva con i processi di neoformazione ossea e guarigione tissutale.

Parole chiave: superficie sabbiata, fluoro, istologia, istomorfometria, microspire, macrospire.

Background and literature's review

The introduction of alternative implant surfaces to the well known and experimented turned surface, improperly called "smooth" has been motivated by better biological responses which the "rough" surfaces seemed to produce, especially in a bone of poor quality and/or associated to regenerative therapies (Hansson and Norton, 1999; Cooper, 2000; Hansson, 2000; Van Stenberghe et al., 2000; Rocci

et al., 2005). Even though histological tests on humans are not numerous in literature, they have confirmed that there is a bigger integration which is expressed in bone-implant contact (BIC) percentage values greater than those obtainable with the turned surfaces (Albrektsson et al., 1993; Ivanoff et al., 2001; Rocci et al., 2002: Ivanoff et al., 2003; Rocci et al., 2003; Schüpbach et al., 2005). This is the reason why different surface typologies have come to light with a modified microtopography as an evolution of the Brånemark turned surface, achieved by using different manufacturer's methodologies. Grouping these surfaces according to the methods used for manufacturing them in order to have those "blasted" characteristics, it can all be narrowed down to two main groups: surfaces roughend either by subtraction or by addiction. The subtraction of a minimum amount of titanium from the surface of an implant can be made by chemical means (acid etching), physical means (blasting or shot peening) or by a combination of the two. The adding techniques see the addition of materials of various nature to the titanium surface, such as hydroxylapatite, titanium dioxide in a plasma-spray form and the titanium dioxide obtained with an anodic oxidation.

Another possible classification is that which takes into consideration the microtopography as a discriminatory parameter, that is the surface geometry of the implant on a micrometric level; following this concept, both Albrektsson and Wennerberg classify the implants as follows: smooth, minimally rough, moderately rough and rough based on the surface area or Sa value. Smooth implants are the ones with an Sa value inferior to 0.5 μm: surfaces having these characteristics are those of the healing abutments, with values ranging between 0.1 and 0.3 μm.

Implants minimally rough show an S_a value within 0.5 and 1.0 μm and are represented by the Brånemark and Astra Tech turned fixtures and those 3i acid-etched. Implants moderately rough all have S_a values ranging between 1.0 and 2.0 μm and practically include all modern implants, such as Astra Tech TiOblast™ and Osseospeed™ , Nobel Biocare TiUnite™ , Straumann SLA and Dentsply Cellplus. Rough implants are the ones with S_a values superior then 2.0 μm, represented by surfaces treated with plasma-spray, and among the modern implants Dentsply Frialit-2 (Albrektsson and Wennerberg, 2004a, 2004b).

The present study has focused its investigation on the implants already equipped with two of the surfaces above mentioned: TiOblast™ and Osseospeed™ , manufactured by Astra Tech Dental AB, Mölndal, Sweden.

The Tioblast surface is manufactured with a physical subtractive procedure, or rather by sandblasting with spheric particles (shot peening) of titanium dioxide the surface, under controlled conditions and with no possibility of contamination. The surface structure is characterized by a well defined topography with a high density of pit of optimized dimension which shows an S_a value of 1.1 μm. A further development of the TiOblast surface is represented by the Osseospeed surface, which is obtained as well as with the sandblasting procedure also with a procedure of chemical type: fluoridation. The titanium surface once sandblasted, is treated with fluoride ions. *In vivo* tests have demonstrated that the presence of dioxide titanium with a negative charge, favours the deposition of calcium ions onto the implant, which in turn show a great affinity with the phosphate groups contained in many organical molecules (proteins, glycans, etc.). the presence of fluoride ions on the implant surface facilitate and strengthen such biological mechanisms; fluoride as a matter of fact (being highly electronegative), increases the speed of sedimentation of the calcium ions and causes an increase in the density of the bone trabecular structure, by stimulating the activity of the osteoprogenitor cells and the alkaline phopshatase, too. It is demonstrated, *in vitro*, the presence of weak secondary bonds between calcium ions and groups of phosphate on a TiOblast surface; whilst such bonds become of a strong covalent type if the surface itself is coated with fluoride ions which are released in the surrounding space following the establishment of such bond (Ellingsen et al., 2000).

Objectives

The objective of the present study is to analyse with a light microscope the potential differences

of the bone response, in humans, comparing a sandblasted implant surface (TiOblast) and a sandblasted surface implemented with fluoride ions (Osseospeed).

Materials and methods

It has been used in the present study implants commercially available on the market but of a smaller dimension (3.5 × 8.0 mm) with a cylindrical profile, screw like morphology and self-tapping, with a developed macrothread on the top up to about 3 mm from the coronal end: this portion has a microthread part, instead. Half of the implants had a microrough surface obtained by sandblasting the surface with titanium dioxide particle (TiOblast), the other half had the same surface but enriched with fluoride ions (Osseospeed). The sample of the candidates taking part in the study was made up by 7 male patients with an age ranging between 40 and 68 years old (mean 60.4), who did not suffer of any pathologies controindicating surgery, nonsmokers and parafunctional free.

The study protocol planned the insertion of one or two couples of implants one next to the other, one for each surface typology, in the inferior maxillary areas edentulous for at least 3 months, within the insertion procedure of placing the implants for the intended rehabilitation. After eight weeks of healing, during the second stage surgery, the biopsies of the fixtures for the study were retrieved together with the perimplant bone tissue by coring with a trephine. The implants, retrieved with the surrounding tissues were immediately placed in a 4% formaldehyde solution and sent to the Department of Biomaterials of the University of Gothenburg, Sweden on the same day. All samples have been dealt with according to the directions of the Department for the histologic procedure of the undecalcified specimens. For this purpose was used the Donath's tecnique of cutting and abrasion (1993) using the Exact system (Exact Apparatebau Co, Nordstedt, Germany). The sections thus obtained were further ground to a 10-15 µm thickness in different phases, and dyed in toluidine blue O and pyronine G. Histologic analysis were done with a light microscope (Eclipse 600 Nikon, Japan) and the hystomorphometric evaluations processed with an image analysis software. Evaluations for each section were performed according to the percentage of bone-implant contact (BIC), in a "blind" manner, with the analyzer not knowing the type of surface being analyzed.

Results

The histologic and hystomorphometric analysis was carried out on five couples of implants which were just a part of the couples considered in the original study protocol. The observation in a light microscope at a low magnification, showed the close contact between the implants' surfaces and the bone tissue (Figs. 1 and 2).

Figure 1
Hystologic section of a TiOblast implant.

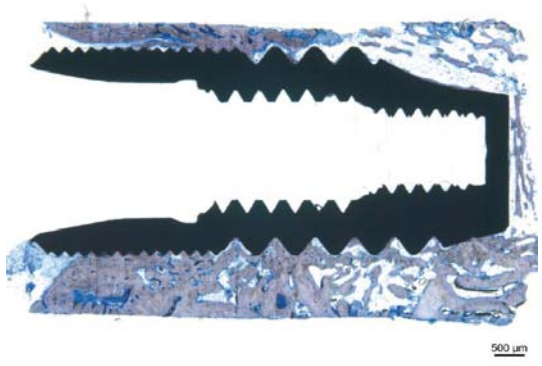

Figure 2
Hystologic section of an Osseospeed implant.

By increasing the magnifications, it was obvious to note the integration process that took place due to both the growth of the osteotomy walls (distant osteogenesis) and to the direct apposition on the implant surfaces (contact osteogenesis) (Figs. 3 and 4). Distant osteogenesis was characterised by bone apposition on the wound margins in the pre-existing bone, contact osteogenesis often appeared as thin linear zones which followed the threads profile.

Cell migration signs from the marrow tissue towards the mineralization front could be identified with larger magnifications, thus indicating recruitment and differentiation of the immature cells from pre-osteoblasts to osteoblasts (Figs. 5 and 6). Haversian systems were identifiable, too.

The bone-implant contact percentage analysis was carried out separately for the two different implant macrogeomtries: the coronal portion (microthread) and the apical one (macrothread). As far as the bone response pertains the zone with the micro-thread, results are shown in tables 1 and 2 with BIC mean values equal to 24.6% for the TiOblast and 34.6% for the Osseospeed (Fig. 7); in three cases the Osseospeed surface has shown a response numerically strong and in two cases the TiOblast surface proved superior (Fig. 8).

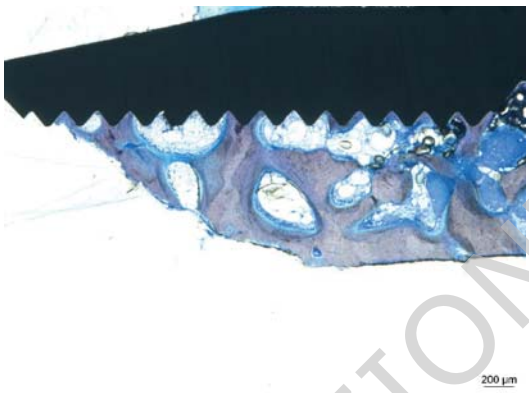

Figure 3
Hystologic section of a microthreaded Osseospeed implant portion.

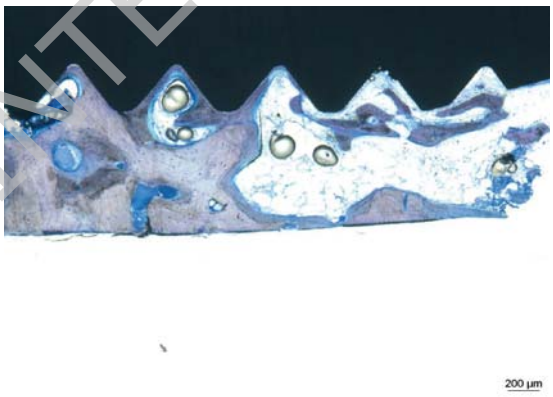

Figure 5
Hystologic section of a TiOblast implant portion.

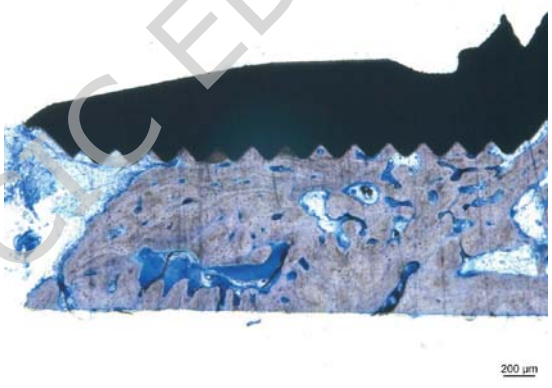

Figure 4
Hystologic section of a TiOblast implant portion.

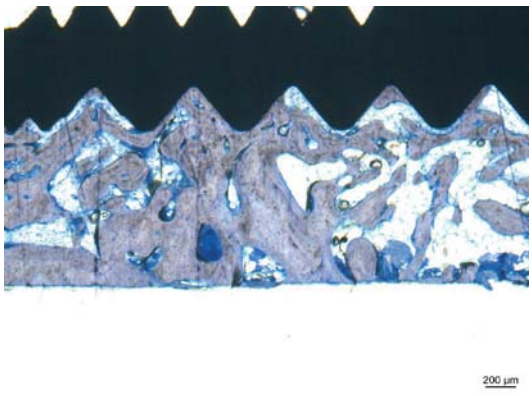

Figure 6
Hystologic section of a microthreaded Osseospeed implant portion.

Table 1 - Values for the microthreaded TiOblast implant portion.

	Bone contact		
Id Nr	**Left side**	**Right side**	**Left + Right side**
Biopsy No 391-06	**13.1**	**0.0**	**6.6**
Biopsy No 393-06	**3.5**	**4.1**	**3.8**
Biopsy No 396-06	**14.4**	**43.4**	**28.9**
Biopsy No 398-06	**67.0**	**57.4**	**62.2**
Biopsy No 399-06	**43.1**	**0.0**	**21.6**

Table 2 - BIC values for the nine microthreaded Osseospeed implant portions.

	Bone contact		
Id Nr	**Left side**	**Right side**	**Left + Right side**
Biopsy No 392-06	**2.2**	**4.8**	**3.5**
Biopsy No 394-06	**22.8**	**50.8**	**36.8**
Biopsy No 395-06	**54.8**	**23.8**	**39.3**
Biopsy No 397-06	**36.8**	**46.7**	**41.8**
Biopsy No 400-06	**43.3**	**60.0**	**51.7**

Hystomorphometric data concerning the apical parts of implants are shown in Tables 3 and 4. The TiOblast surface has shown a BIC median of 24.8% as the Osseospeed surface a BIC median of 48.3% (Fig. 9). In three cases the Osseospeed surface has shown a response decisevely higher, in two cases the TiOblast surface has proved slightly superior (Fig. 10).

Discussion

Within the limits of this study it is possible to confirm what is already in literature about the good performance of modified microtopography surfaces, in terms of bone tissue integration, as previously mentioned. The two surfaces in question,

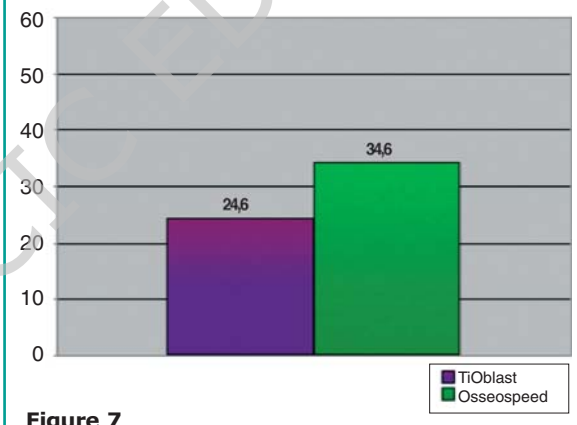

Figure 7
BIC values for the microthreaded portion of each couple of implants.

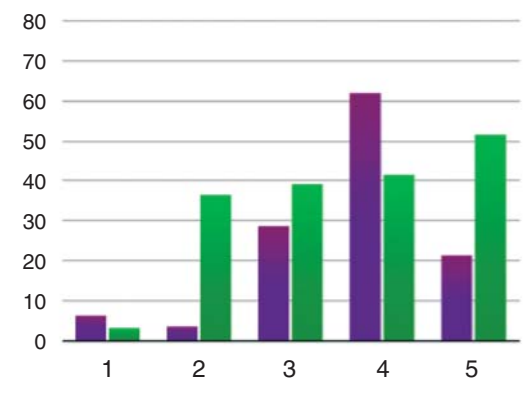

Figure 8
Mean BIC values for the portion of microthreaded implants.

Table 3 - BIC values for the macrothreaded TiOblast implant portion.

	Bone contact		
Id Nr	**Left side**	**Right side**	**Left + Right side**
Biopsy No 391-06	**0.0**	**0.0**	**0.0**
Biopsy No 393-06	**24.9**	**3.9**	**14.4**
Biopsy No 396-06	**57.6**	**46.8**	**52.2**
Biopsy No 398-06	**9.1**	**52.5**	**30.8**
Biopsy No 399-06	**14.9**	**38.6**	**26.8**

Table 4 - BIC values for the macrothreaded Osseospeed implant portion.

	Bone contact		
Id Nr	**Left side**	**Right side**	**Left + Right side**
Biopsy No 392-06	**52.7**	**64.1**	**58.4**
Biopsy No 394-06	**54.0**	**50.9**	**52.4**
Biopsy No 395-06	**44.8**	**41.6**	**43.2**
Biopsy No 397-06	**71.4**	**76.5**	**74.0**
Biopsy No 400-06	**32.0**	**20.4**	**26.2**

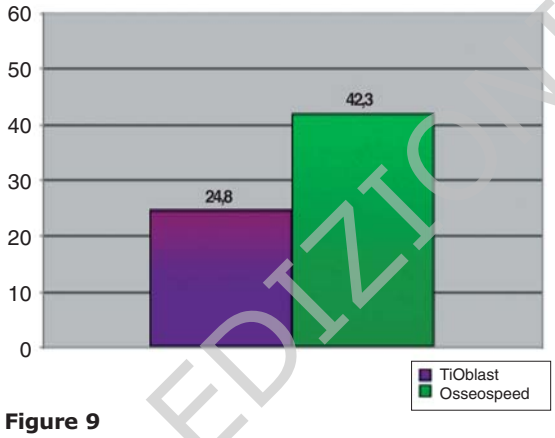

Figure 9
BIC values for the macrothreaded portion of each couple of implants.

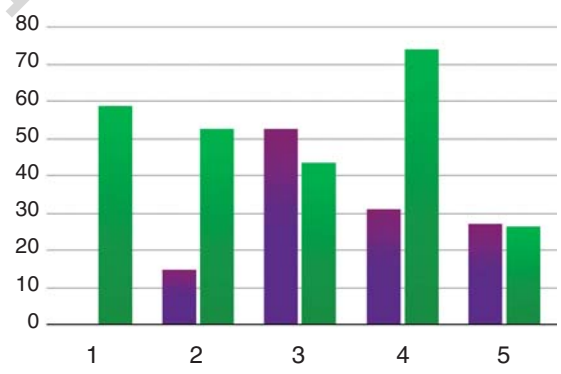

Figure 10
Mean BIC values for the macrothreaded portion of implants.

have expressed to a microscopic level, distant and contact new bone apposition (osteogenesis). Observation with the light microscope would confirm that the Osseospeed implants show a bigger bone deposition, quantitatively-wise, in contact with the surface. Despite the fact that the study has been carried out on a small number of samples, the analysis performed on the mean BIC values for the coronal portion of the implants (microthread), a difference numerically inferior has been noted between the two surfaces compared to that achieved between the mean BIC values for the macrothread portion. According to this it can be assumed that – nonetheless the small number of samples – there are biological mechanisms which could explain the homogeneity of the results at the interface. The

coronal portion of the implant is in contact with bone of a cortical kind, which both for the histological characteristics and for the position in the surgical site, shows healing mechanisms of its own different from the ones which affect the medullar compartment. Cortical bone is characterised by a dense cancellous structure and makes the tissue particularly hard and little elastic; to these characteristics it can be added a scarce cellularity and very little vascularization all elements which favor slower healing processes. This phenomenon is enhanced by the mechanical stress which the cortical bone undergoes both during site preparation for surgery and while inserting the fixture; in biological terms the postinsertion bone remodelling will be greater at the interface. Furthermore, both a scarce vascularization and a scarce cellularity, delay the start of the early healing phases even because osteoblasts are cells incapable to migrate and replicate autonomously. Osteoblast cells activate themselves as a response to the presence of precursor cells deputed to osteogenesis (DOPC, Determined Osteogenic Precursor Cells) (Friedestein, 1973) and are commonly located in proximity of the blood vessels and close to the bone surface. Bearing this picture in mind, it is necessary to remember that the role fluoride plays is fundamental during the early phase of the healing process as being highly electronegative and enhances the initial Calcium ion deposition on the implant's surface more rapidly and thus guaranteeing the formation of a strong covalent bond between the titanium and calcium dioxide. By forming this bond fluoride enters in solution and its action is exhausted. Due to the precociousness of this mechanism and considering the longer times in which the peri-implant cortical rstorative processes take place, it can be assumed that fluoride does not play a role such as to greatly affect the different times of osteointegration in the coronal portion of the implant. What appears interesting is the analysis performed on the BIC values for the apical portion (macrothread). The difference between the mean values was decisively higher (the mean BIC values for the test surface have values almost the double compared to the values of the control surfaces), therefore it can be assumed that the role of fluoride is probably more relevant in this area. The cancellous bone tissue is highly cellular and vascular compared to the compact one, and is characterized by a bigger trabecular meshwork structure that gives the tissue a higher elasticity.

Considering the fact that the mechanical stress in the apical portion of the bone is definitely smaller both during the preparation of the implant site and the insertion of the fixture, and the histological characteristics confer a greater capacity to endure stress, it can be easily understood how the neo bone apposition processes can start faster and therefore the fluoride presence might positevely influence the healing times and thus those of the osteointegration.

Conclusions

Considering all the limits this study has, and in a short while it will be completed by analysing five more pairs of Tioblast and Osseospeed implants, preliminary results achieved allow us to make hypothesis and reasonings susceptible of future confirmation.

The most interesting hypothesis could be that by implementing the implant surfaces with fluoride, represents a first significant step towards making bioactive prosthesis devices and not just biocompatible or "biotolerated".

It seems evident, should the hypothesis drawn from the data produced in this study be confirmed in the future, that there will most probably be important clinical implications concerning the reduction in time's procedures for the functionalization and immediate rehabilitation of those situations of poor bone quality (D3 and D4) and of biologic challenge such as bone grafting procedures.

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