Influence of implant design on osseointegration

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Fig. 1_Implant tested – D.
Fig. 2_Reference implant – B.
Fig. 3_Drilling of implant wells.
Fig. 4_Positioning of the implants on the maxilla.
Fig. 5_Implants in place.
Fig. 6_Periimplant bone organisation.

_Introduction


Fig. 1


Fig. 2

Nowadays, numerous studies attempt to show the importance of implant surface treatment[1] for accelerating the osseointegration process.[2] Surface finishing, notably roughness generation, has allowed to increase the ability of titanium to link directly to bone without any intermediary fibrous tissue.[3] Thus, it seems that if the osteoblast response is obviously measured by histology, it does not inform on long-term implant success but only on the cell organisation of the peri-implant bone tissue and it provides no information on the architecture of this tissue.[4] Only the study of newly-formed trabecular bone tissue around the implant can provide predictive results concerning implant durability. Trabecular tissue forms only 20 per cent of the skeletal mass but 80 per cent of the exchange surface between bone and marrow. This microstructure plays a mechanical role because it ensures that the external loads be correctly distributed in the bone volume. Due to its mechanical function, trabecular bone is a preferential site to study the spatial and geometrical properties of this bone tissue and the interaction between medical apparatus and bone tissue. The future of a dental implant after loading mainly depends on: trabecular organisation, intimacy of contact between metal structure and bone, surrounding bone volume, bone density.[5] The aim of the present work was to characterise the periimplant bone organisation and to evaluate the influence of implant shape on osseointegration, using a porcine model. Implantations were carried out on growing piglets on maxilla and trabecula, because the experimental results published up to now mostly concern fixtures set on tibia or iliac of pork or dog (results so obtained concern mainly cortical bone and less trabecular bone).[6]

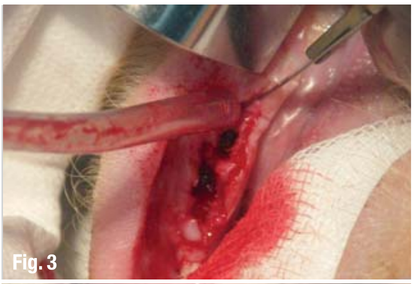


Fig. 3


Fig. 4


Fig. 5

Fig. 6

_Material and method

28 implant fixtures (diameter 3.5 mm, length 7 mm) were set in the jawbones of eight pigs, 16 in the mandible and 12 in the maxilla. Two types of implant were used: implant B with a cylindrical body and implant D presenting a shrink under its neck as shown in Figs. 1 and 2. Histomorphometric analysis was carried out on samples taken 45 days after implantation. Samples were analysed with a resolution of 18 µ.

_Animal experiments

Experiments were carried out on eight pigs of mean weight of 12.1 kg at day 0 and 32.3 kg when sacrificed. Initial denture is mixed, complete and healthy for each animal. The project was presented to the ethic comity of Institute of Experimental Surgery (ICE) of Centre Léon Bérard (Lyon, France). Animal choice and care, and experimental procedure were approved by the committee.

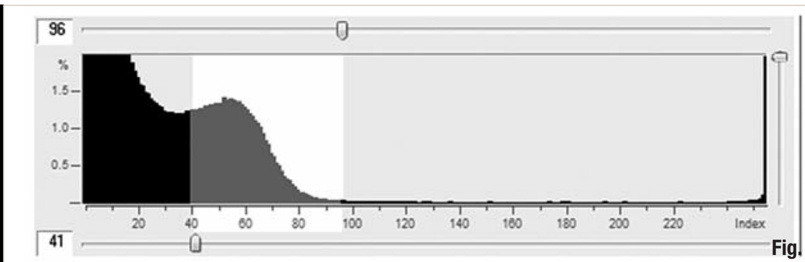
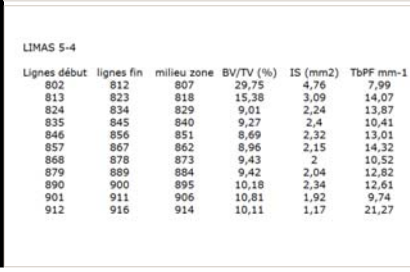


Fig. 8



LIMAS 5-4

Lignes début	lignes fin	milieu zone	BV/TV (%)	IS (mm2)	TbPF mm-1
802	812	807	29,75	4,76	7,99
813	823	818	15,38	3,09	14,07
824	834	829	9,01	2,24	13,87
835	845	840	9,27	2,4	10,41
846	856	851	8,69	2,32	13,01
857	867	862	8,96	2,15	14,32
868	878	873	9,43	2	10,52
879	889	884	9,42	2,04	12,82
890	900	895	10,18	2,34	12,61
901	911	906	10,81	1,92	9,74
912	916	914	10,11	1,17	21,27

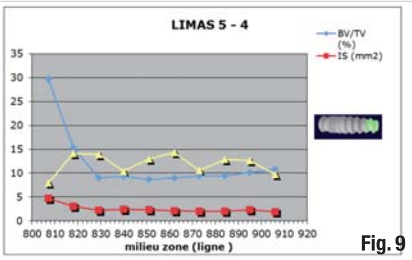


Fig. 9

_Operating protocol

The placement of the implants was achieved in the operating room under general anaesthesia. Animals received medication performed according to the following protocol: Intramuscular premedication injection: 3 à 5 ml/kg of Imalgène 1000 + 0.1 ml/kg of Stresnil + 1 ampoule of atropine; Intravenous induction of general anesthesia: 0.003 ml/kg of the XKZ mixture (Xylazine, Kétamine, Zolazepam) for a duration of about 30 minutes. Mandibular implants were placed in the space between canine and first premolar, and maxillary implants were placed either distally of the lateral incisor or mesially of the first premolar.

_Surgery technique

It was the same as in human oral surgery: asepsis of the surgery field, crestal incision, localisation of the implant site, boring, threading, implant placement, suturing of gingival flap with interrupted sutures separated stitches. Referenced titanium implants were used (Figs. 1–5).

_Operating hazards

The main difficulty arose from insufficient height and thickness of the alveolar crest in the mandibular sites and to the relatively important size of the nasal cavities on maxillary sites, which imposes to use implants of low diameter and height. Some implants were lost due to a supracrestal or crestal positioning which did not resist animal tongue forces. An infectious event also occurred, resulting in the exclusion of one animal from the study.

_Sample collection

Samples were collected at day 45, after anaesthesia of the animal, following the protocol established with the ethic committee. Bone was cut with a mechanical saw around the implant sites. Samples were immerged in formaldehyde and transferred to the imaging department for histomorphometric analysis.

_Histomorphometric analysis[7]

Analysis was conducted with CtAn™ software (SkySkan™) dedicated to scanner imaging. Bone histomorphometry consisted in the measurements of the parameters reflecting bone structure, microarchitecture and remodelling. The study of samples including bone and implant permits us to visualize the bone architecture around the implant from neck to apex, with the osseointegration phase being at its terminal stage.

Parameters considered for result analysis[8]
- BV/TV (%): ratio between bone volume and tissue volume; depending on the depth of the analysed volume, V represents cortical or trabecular bone.
- IS (mm²): surface of bone intersection with implant structure.
- TbPF (mm^{-1}): trabecular pattern factor, quantifying the interconnection of the bone (ratio between the numbers of concave and convex surfaces, quantifying the connections inside a 3-D structure).
- BS/TV (%): reflecting the density of the bone mesh.

Analysis methodology (Figs. 6–8)

A step-by-step analysis as a function of implant depth can be effected by a block of ten frames, each block corresponding to a slice of a thickness of 180 µm. Corresponding data were plotted as a function of depth, depth being defined as the centre of the slice. An example of results is shown in Fig. 9. A global analysis of data corresponding to the sum of all slices was done next. For this volume of interest

Fig. 7_3-D representation of bone surrounding the implant: the choice of low and high threshold values allows to eliminate metal and any soft tissue.

Fig. 8_Corresponding histogram: for this example the selected range (41–96) is taken into account as bone tissue.

Fig. 9_Illustration of the histomorphometric analysis method, data are plotted as a function of depth along implant.

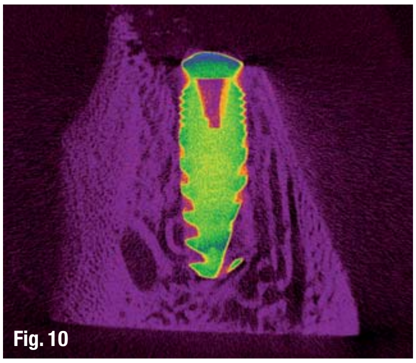


Fig. 10

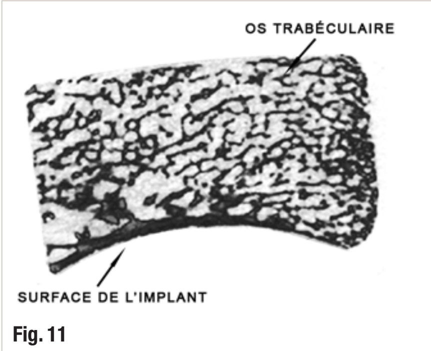


Fig. 11

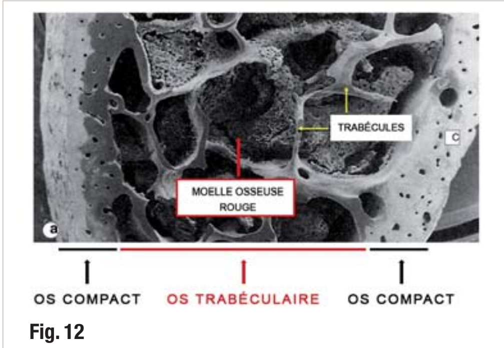


Fig. 12

Fig. 10_Front section view of the whole implant, showing the periimplant osseointegration.
Fig. 11_Transverse section view: contact between implant surface and trabecular bone.
Fig. 12_Histological section of trabecular bone.

one obtained: BV/TV = 12 %, IS=14 mm^2, BS/TV = 6.2 mm^{-1} and TbPF = 1.13 mm^{-1}.

_Result analysis: relation between parameters[10]

At implant neck

The depth evolution of the ratio between trabecular bone volume and tissue volume is superimposable with the shape of the implant neck. IS is approximately constant, which corresponds to a satisfactory adhesion between the bone surface and the implant surface.

TbPF follows a curve symmetrical to the one of BV/TV: spongy trabecular bone is well organized and linked. BS/TV presents a mean value about 6, corresponding to an interesting bone density.

At implant apex

As shown in Fig. 9, the BV/TV curve follows the implant shrinkage jumping from 30 up to a plateau at about 10. TbPF varies from 8 about a screw turn hollow, follows the apex shape with a mean value of 13 and ends to 21. IS presents a plateau at 1.75.

Comparison between the two types of implants

Fig. 13 and 14 illustrate the comparison between two implants placed at the same position in the anterior maxillary sites.

At implant neck:

Implant B (cylindrical neck): BV/TV varies from 2 to 21, IS varies from 1.6 to 7.2, TbPF varies from 20 to 30 and then up to 8.2 under the neck, BS/TV varies from 2 to 8.

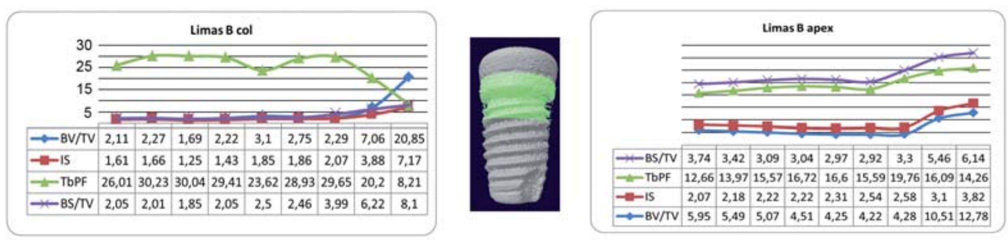
Implant D (shrunk neck):

BV/TV varies from 10 to 15, IS varies from 3.7 to 3, TbPF varies from 14 to 28 and then up to 2.9 under the neck, BS/TV varies from 5 to 11. It is noticeable that BV/TV and BS/TV are higher with the shrunk neck, while TbPF is slightly better with a cylindrical neck.

At implant apex:

Implant B: BV/TV varies from 6 to 13, IS varies from 2.1 to 3.8, TbPF varies from 12.7 to 14.3, BS/TV varies from 4 to 6.

Implant D: BV/TV varies from 7 to 21, IS varies from 1.6 to 3.3, TbPF varies from 14.4 to 23, BS/TV varies from 4.1 to 4.4.



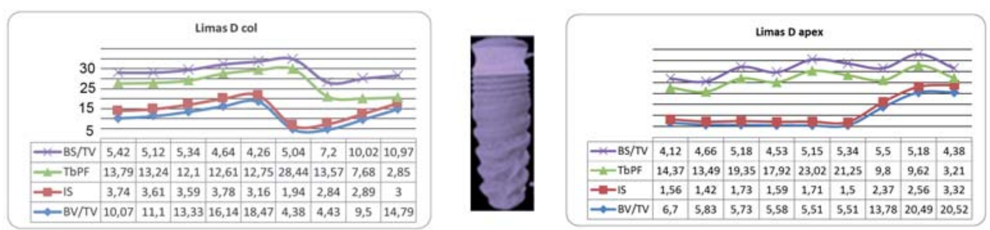
Limas B col

BV/TV	2,11	2,27	1,69	2,22	3,1	2,75	2,29	7,06	20,85
IS	1,61	1,66	1,25	1,43	1,85	1,86	2,07	3,88	7,17
TbPF	26,01	30,23	30,04	29,41	23,62	28,93	29,65	20,2	8,21
BS/TV	2,05	2,01	1,85	2,05	2,5	2,46	3,99	6,22	8,1

Limas B apex

BS/TV	3,74	3,42	3,09	3,04	2,97	2,92	3,3	5,46	6,14
TbPF	12,66	13,97	15,57	16,72	16,6	15,59	19,76	16,09	14,26
IS	2,07	2,18	2,22	2,22	2,31	2,54	2,58	3,1	3,82
BV/TV	5,95	5,49	5,07	4,51	4,25	4,22	4,28	10,51	12,78

Fig. 13



Limas D col

BS/TV	5,42	5,12	5,34	4,64	4,26	5,04	7,2	10,02	10,97
TbPF	13,79	13,24	12,1	12,61	12,75	28,44	13,57	7,68	2,85
IS	3,74	3,61	3,59	3,78	3,16	1,94	2,84	2,89	3
BV/TV	10,07	11,1	13,33	16,14	18,47	4,38	4,43	9,5	14,79

Limas D apex

BS/TV	4,12	4,66	5,18	4,53	5,15	5,34	5,5	5,18	4,38
TbPF	14,37	13,49	19,35	17,92	23,02	21,25	9,8	9,62	3,21
IS	1,56	1,42	1,73	1,59	1,71	1,5	2,37	2,56	3,32
BV/TV	6,7	5,83	5,73	5,58	5,51	5,51	13,78	20,49	20,52

Fig. 14

Fig. 13_Example of results at the neck and apex for implant B (control).
Fig. 14_Example of results at the neck and apex for implant D.

One observes that IS and BV/TV curves have the same pattern for implants B and D, but with lower values for B implant. Moreover, TbPF presents lower values for implant B, but TBPF does not decrease at the apex for implant B. For implant D, bone density is constant along the implant, the TbPF curve is superimposable with the BV/TV one, revealing a good trabecular architecture, IS is constant and BV/TV increases up to apex.

_Conclusions

Osseointegration is defined as a direct anatomic and functional junction between living bone and implant surface. Osseointegration is determined by several factors linked to the host and to the implant. On a biological point of view, osseointegration occurs in two phases: the first one consists in a mechanical stabilisation and anchorage in the prepared site; the second phase is characterised by the formation of a biological cohesion between implant surface and bone tissue.

The present study is an investigation on histomorphometric analysis of osseointegration. The preliminary results indicate that bone volume and bone density would recover better with a shrunk neck shaped as a Bone Launching Pad™ (implant D) than with a cylindrical neck. It is the same for the surface intersection between bone and implant, which appears to be larger, revealing denser bone around the implant. Concerning the body and apex of the implant, the more spaced turns of implant D would favour the bone density along the implant body and a higher and more uniform ratio between trabecular bone and tissue volumes. The trabecular architecture seems thus to be impacted by the shape of implant neck and apex._

Editorial note: A list of references is available from the publisher.

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