MORPHOLOGIC ANALYSIS OF COMPUTER TOMOGRAPHY IMAGES - 2ND GENERATION IMPLANTS -

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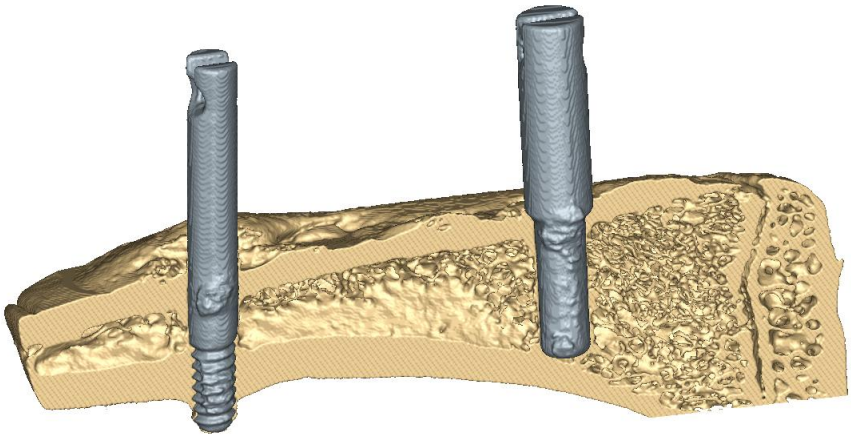

Contents:

1. INTRODUCTION

It is presented a qualitative analysis on the morphology of the 2nd generation rat implants. The images from the Computer Tomography (CT) refer to the titanium implants fixed on the rat femur. Each specimen is composed by three elements:

- Distal threaded implant that provides the anchorage.
- Proximal implant with diameter variation.
- Rat femur.

The purpose of this analysis is the identification of standard features of each group of specimens and the comparison with the results obtained with the previous set of experiment (*"Analyse morphologique des image CT obtenues lors de la Phase I – Rapport intermédiaire – Marzio Bergomi, Joël Cugnoni, John Botsis"*).

2. METHOD

The images from the CT have been elaborated with the software ITK-Snap (J. Cugnoni version) in order to obtain a segmented three-dimensional representation of each specimen. This 3D view allows to evaluate the characteristics of the implants and the morphology of the bone around them. The formats of the files are *DICOM* and *gipl* for the CT images and the segmented files respectively.
In agreement with the first qualitative analysis (M. Bergomi), the morphological features related to the distal and proximal implant are summarized in Tab. 1 and 2 respectively.
In Fig. 1 is represented a specimen and the considered areas of interest.

TABLE 1. MORPHOLOGICAL FEATURES OF THE DISTAL IMPLANT.

Cortical on top	"pont"	Thin area of cortical bone around the implant.
	Fixed/Free distal	The cortical bone touch or not the implant in the distal, proximal or transversal area.
	Fixed/Free proximal	
	Fixed/Free transversal	
	Normal/conic distal	The shape of the cortical bone around the implant is normal or conic.
	Normal/conic proximal	
	App/res distal	Apposition or resorption near the implant (to compensate a weakening of the structure) in the distal, proximal or transversal area.
	App/res proximal	
	App/res transversal	
Alveolar	App/res on top	Apposition or resorption of trabecular bone around the implant on top, in the middle or below.
	App/res middle	
	App/res below	
Cortical below	App/res distal	Apposition or resorption of cortical bone around the implant in the distal, proximal or transversal area.
	App/res proximal	
	App/res transversal	

TABLE 2. MORPHOLOGICAL FEATURES OF THE PROXIMAL IMPLANT.

Cortical on top	"pont"	Thin area of cortical bone around the implant
	Fixed/Free distal	The cortical bone touch or not the implant in the distal, proximal and transversal area.
	Fixed/Free proximal	
	Fixed/Free transversal	
	Normal/conic distal	The shape of the cortical bone around the implant is normal or conic.
	Normal/conic proximal	
	App/res distal	Apposition or resorption near the implant (to compensate a weakening of the structure) in the distal, proximal and transversal area.
	App/res proximal	
	App/res transversal	
Alveolar	App. Proximal	Apposition or resorption of trabecular bone around the implant quite proximal, distal or uniform.
	App. Distal	
	App. Uniform	
Cortical below	Implant in/out	The implant touch or not the cortical bone.

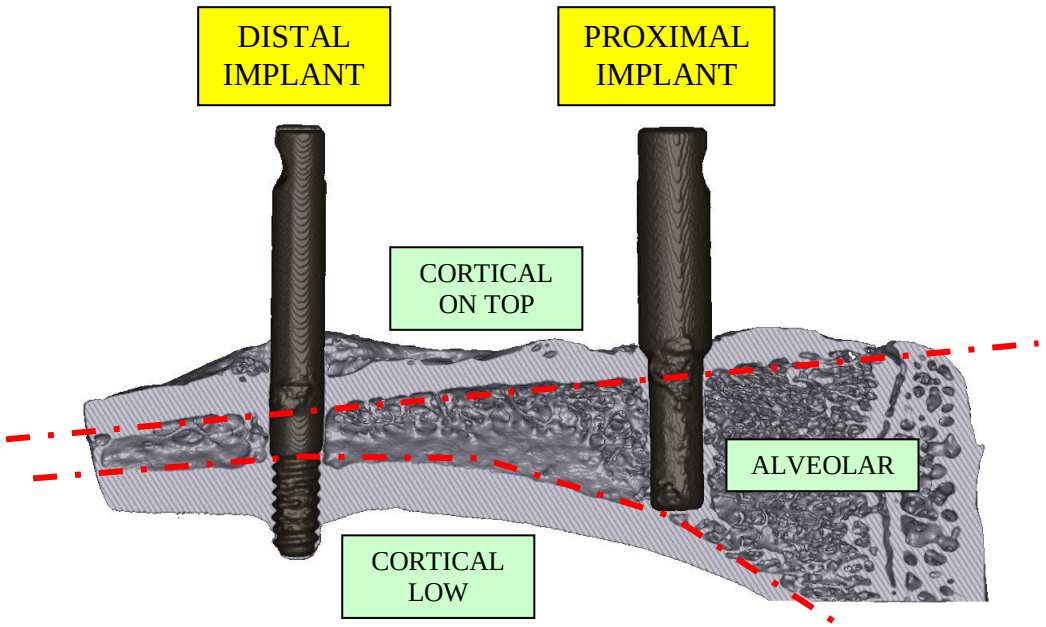

FIG. 1. AREAS OF INTEREST EXAMINATED DURING THE MORPHOLOGICAL ANALYSIS.

The feature that point out a good integration of the implant is marked with the positive value (1) and the green colour, while the bad integration of the implant is marked with a negative value (-1) and the red colour. The Yellow colour and the value 0 are used to put in evidence an undefined situation.
With to regards Table 1 and 2, it is important to note that the green colour correspond to the first option for each listed feature names: apposition and resorption are +1 and -1 respectively.

A new analysis of five random specimens belonging to the first set up of experiments (initially treated by M. Bergomi) has been done in order to check the repeatability of the method. The results confirm the compatibility of the present study compare to the previous one: the two evaluations are completely similar for the 94% of the features and the remaining 6% only differs between intermediate values (green and yellow or yellow and red) but never between opposite values (red and green).

The results for the second generation tests are represented in Fig. 2.

3. RESULTS

In this paragraph are presented the results reported in Fig. 2. The percentages are used to put in evidence the relevance of positive feature (green coloured) on the overall. As specified previously, this analysis has to be considered as purely qualitative.

DISTAL	On top:	56% of the distal implants are completely fixed to the bone in the upper part and only a 7.5% presents a conic shape. In the 26% of the specimens an apposition far from the implant is present.
	Alveolar:	61% of the implants are well integrated and the trabecular bone structure is present.
	Below:	88% of the threaded implants are well fixed to the low part of the cortical bone.
PROXIMAL	On top:	86% of the proximal implants are integrated in the upper part of the bone and only 15% have a conic shape. In only 4% of the specimens an apposition far from the implant is present.
	Alveolar:	The 90% of the titanium implants are well integrated in the trabecular bone and present a uniform structure.
	Below:	The 72% of the proximal implants touch the lower part of the cortical bone.

1	DISTAL	SPECIMENS																															
2	**Cortical haut**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
3	Pont	-1	-1			-1	1	1			1	1	1	-1	-1		1	1	1		-1	-1	1	-1	1	-2	1	-1	-1	-1		1	-1
4	E/F distal	-1	-1			-1	1	1			1	1	1	-1	-1		1	1	1		1	-1	1	-1	1	-2	1	-1	-1	-1		1	-1
5	E/F proximal	-1	-1			-1	1	1			1	1	1	-1	-1		1	1	1		-1	-1	1	-1	1	-1	1	-1	-1	-1		1	-1
6	E/F transverse	-1	-1			-1	1	1			1	1	1	-1	-1		1	1	1		1	-1	1	-1	1	-1	1	-1	-1	-1		1	-1
7	N/C distal	0	0			0	1	-1			1	1	-1	0	0		-1	1	1		1	0	1	0	-1	0	0	0	0	0		0	0
8	N/C proximal	0	0			0	1	0			1	1	1	0	0		1	1	1		0	0	1	0	-1	0	0	0	0	0		0	0
9	A/R distal	1	1			1	1	0			0	0	0	0	1		0	1	1		1	0	1	1	0	0	0	0	0	1		0	1
10	A/R proximal	-1	1			1	0	1			0	0	1	0	0		0	1	0		1	0	0	0	0	0	0	0	0	0		0	0
11	A/R transverse	0	1			1	1	1			0	0	0	0	0		1	1	0		1	1	1	0	0	0	0	1	0	0		0	0
12	**Alveolar**																																
13	A/R haut	-1	-1			-1	1	-1			1	1	1	-1	-1		1	1	1		1	-1	1	0	1	-1	1	0	0	0		1	-1
14	A/R centre	0	0			-1	1	-1			1	1	1	0	0		1	1	1		1	0	1	0	1	0	1	0	0	0		1	0
15	A/R bas	1	1			-1	1	1			1	1	1	1	1		1	1	1		1	1	1	1	1	1	1	0	0	0		1	1
16	**Cortical bas**																																
17	A/R distal	1	1			1	1	1			1	1	1	1	1		1	1	1		1	0	1	0	1	0	1	1	1	1		1	1
18	A/R proximal	1	1			1	1	1			1	1	1	1	1		1	1	1		1	0	1	0	1	0	1	1	1	1		1	1
19	A/R transverse	1	1			1	1	1			1	1	1	1	1		1	1	1		1	0	1	0	1	0	1	1	1	1		1	1
20	PROXIMAL	SPECIMENS																															
21	**Cortical haut**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
22	E/F distal	-1	1			1	1	1			1	-1	1	1	1		1	1	1		1	1	-1	1	1	1	1	1	1	1		1	1
23	E/F proximal	-1	1			1	1	1			1	-1	1	1	1		1	1	1		1	1	-1	1	1	1	1	1	1	1		1	1
24	E/F transverse	-1	1			1	1	1			1	-1	1	1	1		1	1	1		1	1	-1	1	1	1	1	1	1	1		1	1
25	N/C distal	0	1			1	1	1			-1	0	1	1	1		1	1	1		1	1	0	1	1	1	1	1	1	1		-1	-1
26	N/C proximal	0	1			1	1	1			-1	0	1	1	-1		1	1	1		1	1	0	1	1	1	1	1	1	1		1	-1
27	A/R distal	0	0			1	0	0			0	0	0	0	0		0	0	0		0	0	0	0	0	0	0	0	0	0		0	0
28	A/R proximal	0	0			0	0	0			0	0	0	0	0		0	0	0		0	0	0	0	0	0	0	0	0	0		0	0
29	A/R transverse	1	1			0	0	0			0	0	0	0	0		0	0	0		0	0	0	0	0	0	0	0	0	0		0	0
30	**Alveolar**																																
31	Proximal																																
32	Distal	1																					1										
33	Uniform		1			1	1	1			1	1	1	1	1		1	1	1		1	1		1	1	1	1	1	1	1		1	1
34	**Cortical bas**																																
35	implant out/in	-1	1			1	-1	-1			-1	-1	1	-1	-1		-1	-1	-1		-1	1	-1	1	1	1	1	-1	-1	1		-1	-1

1	DISTAL	SPECIMENS																															
2	**Cortical haut**	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
3	Pont	-1	-1	1	1		1	-1			1		1	-1	-1			-1	1	1	1	1		1			1	-1	-1		0	1	-1
4	E/F distal	-1	-1	1	1		1	-1			1		1	-1	-1			1	1	1	1	1		1			1	-1	-1		1	1	-1
5	E/F proximal	-1	-1	1	1		1	1			1		1	-1	-1			-1	1	1	1	1		1			1	-1	-1		0	1	-1
6	E/F transverse	-1	-1	1	1		1	1			1		1	-1	-1			0	1	1	1	1		1			1	-1	-1		1	1	-1
7	N/C distal	0	0	1	1		1	0			1		-1	0	0			1	1	1	-1	1		1			1	0	0		1	1	0
8	N/C proximal	0	0	1	1		1	1			1		1	0	0			0	1	1	1	1		1			1	0	0		1	1	0
9	A/R distal	0	0	0	1		0	1			0		0	1	0			0	0	0	0	0		0			0	0	0		0	0	1
10	A/R proximal	0	0	0	0		0	0			0		0	0	0			0	0	0	0	0		0			0	0	0		0	0	1
11	A/R transverse	0	1	0	0		0	0			1		0	0	0			0	0	0	0	0		0			0	0	0		0	1	1
12	**Alveolar**																																
13	A/R haut	-1	0	1	1		1	0			1		1	-1	-1			-1	1	1	1	1		1			1	-1	-1		-1	1	-1
14	A/R centre	-1	0	1	1		1	0			1		1	0	0			-1	1	1	1	1		1			1	-1	-1		-1	1	-1
15	A/R bas	-1	0	1	1		1	0			1		1	1	1			1	1	1	1	1		1			1	-1	1		1	1	0
16	**Cortical bas**																																
17	A/R distal	1	1	1	1		1	1			1		1	1	1			0	1	0	1	1		1			1	0	1		1	1	1
18	A/R proximal	1	1	1	1		1	1			1		1	1	1			1	1	0	1	1		1			1	0	1		1	1	1
19	A/R transverse	1	1	1	1		1	1			1		1	1	1			1	1	0	1	1		1			1	0	1		1	1	1
20	PROXIMAL	SPECIMENS																															
21	**Cortical haut**	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
22	E/F distal	1	1	1	1		-1	1			1		1	1	1			1	1	1	1	-1		1			1	1	1		1	1	1
23	E/F proximal	1	1	0	0		-1	1			1		1	1	1			1	1	1	1	-1		1			1	1	1		1	0	1
24	E/F transverse	1	1	1	1		-1	1			1		1	1	1			1	1	1	1	-1		1			1	1	1		1	0	1
25	N/C distal	-1	1	-1	1		0	1			1		1	1	1			1	1	1	1	0		1			-1	1	1		1	1	1
26	N/C proximal	-1	1	-1	1		0	1			1		1	1	-1			1	-1	1	1	0		1			-1	1	1		1	0	1
27	A/R distal	0	0	0	0		0	0			0		1	0	0			0	0	0	0	0		0			0	0	0		0	0	0
28	A/R proximal	0	0	0	0		0	0			0		0	0	0			0	0	0	0	0		0			0	0	0		0	0	0
29	A/R transverse	0	0	0	0		0	0			0		0	0	0			0	0	0	0	0		0			0	0	0		0	0	1
30	**Alveolar**																																
31	Proximal						1																										
32	Distal																					1											
33	Uniform	1	1	1	1			1			1		1	1	1			1	1	1	1			1			1	1	1		1	1	1
34	**Cortical bas**																																
35	implant out/in	-1	1	-1	-1		-1	-1			-1		1	-1	-1			1	-1	-1	-1	-1		-1			-1	-1	-1		-1	1	-1

FIG. 2. RESULTS FOR THE 2ND GENERATION IMPLANTS.

4. DISCUSSION

The results shown in Fig. 2 allow us to draw the following considerations:

- Even if the proximal implant touches the lower part of the cortical bone in most of the cases, it does not influence the good integration in the upper part of alveolar and cortical bone.
- In few specimens an apposition is present far from the implant, in particular in the case of distal implants with a bad integration (inflammation reaction?). Otherwise the bone reacts well to the implantation. No external remodelling seems necessary to structurally compensate the presence of the implants.
- The distal implant presents a perfect integration in most of the specimens characterized by a bad integration of the proximal implant in the upper cortical bone (and vice versa). It may be the result of a stiffness adaptation of the bone that avoids over-loaded regions. To be checked by simulation in the future.
- A lot of distal implants are well integrated in the lower cortical bone, even if a part of the threads is not involved in the remodelling. The external profile of the bone surface is respected.
- The generation of new alveolar bone is tightly dependent on the remodelling of upper cortical bone in the area of insertion of the implants.

5. CONCLUSIONS

The set of experiments considered in this report presents several improvements with respect the one examined by M. Bergomi in 2009.
For what concern the proximal implant, the variation of diameter avoids the migration of the implant to the lower part of the cortical bone, as it was expected. The good integration of the implant in the upper part of the cortical bone allows the generation of a detailed trabecular reticulum in the alveolar section. If, after integration, the implant touches the cortical bone in the lower part, the type of bone (trabecular or cortical) generated in this area is not clear and difficult to establish.
For what concerns the distal implant, the threaded part is generally well fixed to the cortical bone even if a part of the thread is outside the bone. A confirmation of the good integration is the absence of inflammation or external apposition in the region of the lower cortical and the normal profile of the bone surface is preserved.
The upper part of the distal implant presents the highest frequency of “failure”, influencing also the generation of trabecular bone in the alveolar area. Similarly, the upper cortical region around the distal implant seems the most affected by external apposition / inflammatory reactions.
Compared to the previous set of experiments, the enhancements are evident. Further observations are necessary in order to detect the reasons of the worse integration of the distal implant.