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La réhabilitation du maxillaire atrophique : autogreffe osseuse et implants conventionnels *vs* implants zygomatiques

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Liste des abréviations

CI: conventional implants

ABG: autogenous bone grafting

LFIO: Le Fort I osteotomy

ZI: zygomatic implants

IBFD: implant-borne fixed denture

OHRQoL: oral health-related quality of life

IQR: interquartile range

1. Introduction

As Brånemark said, “the edentulous patient is an amputee, an oral invalid, to whom we should pay total respect and rehabilitation ambitions”; however, management of an edentulous maxilla or presenting a terminal dentition is a real challenge if the patient wants a fixed denture, in particular when a generalized bone atrophy is present. In this case, conventional implants (CI) placement is impossible given the maxillary sinus pneumatization associated with severe alveolar bone loss (1). Loss of bone may be explained by medical histories marked by dental extractions or traumatic avulsions, severe periodontitis, or iatrogenic ill-fitting removable denture (2).

This major oral disease entity as described by Atwood (3) has severe consequences on oral and general physical and mental health explained notably by a significant impairment of masticatory function linked with unhealthy diet, deterioration of facial appearance and phonation, social deprivation and exclusion can be correlated too (4).

Surgical management appearing to be the most reliable and the most reported in the literature with a significant clinical experience is autogenous bone grafting (ABG) which can be combined with a Le Fort I osteotomy (LFIO) if an inverted interarch relationship with dentoskeletal class III malocclusion exists (5). High grafting success rates associated with high implant success/survival rates and low complication rates are found in the literature (6) (7) (8) (9) (10) (11) (12).

A second solution for management of the atrophic maxilla is zygomatic implants (ZI) placement. This most recent alternative graftless approach is also based on long-term clinical experience since the description of the surgical technique by Brånemark in 1998 (13). The literature describes very good results too with comparable high implant success/survival rates, high prosthetic survival rate and low complication rates (14) (15) (16).

ZI seem to be the most attractive option with less morbidity and reduced treatment duration. All the management is gathered in one surgical step: dental extractions if patient has a terminal dentition, ZI placement, with the fitting of a full-arch implant-borne fixed denture (IBFD) on the day or the next day of surgery

thanks to a very high primary stability related to their anchorage in the zygomatic bone (17) (18).

To the contrary, grafting protocol has a priori greater morbidity and two surgeries are needed: ABG as a first step, then CI placement three to six months after. Prosthetic procedures begin three to six months after CI placement. This treatment can therefore spread over a 12-month period or more (19) (12) (20), and will be extended if teeth must be extracted before grafting–3 months of healing (21).

In the literature, no study compares clinical outcomes and postoperative quality of life between ABG followed by CI placement and immediate loaded ZI placement for the fixed rehabilitation of the atrophic maxilla.

Thus, the aim of this study was to compare these two protocols on oral health-related quality of life (OHRQoL). Secondarily, we also discussed postoperative morbidity and patient satisfaction, implant survival rate, occurrence of potential postoperative biological complications and prosthetic follow-up.

2. Materials and methods

2.1 Sample

All patients who benefited from ZI procedure or ABG followed by CI placement in our oral and maxillofacial surgery department for the fixed rehabilitation of an atrophic maxilla, from November 2011–date on which we placed our first ZI in a patient–to April 2019, were included.

All of them presented a severely atrophic maxilla characterized by a class V or VI in the Cawood and Howell's classification (22) in both zone II (bicuspid zone) and III (posterior maxilla) according to the preoperative evaluation described by Bedrossian (23). In addition, some of them presented a severely atrophic maxilla in zone I (premaxilla).

Patients with congenital defect or who underwent maxillectomy for tumor resection, and for which they benefited from ZI placement, were not included in the study. Patients with anodontia, for which they benefited from ABG followed by CI placement, were not included in the study either.

Exclusion criteria were incomplete documentation, uncompleted management of the patient or the refusal to answer the Oral Health Impact Profile-14 questionnaire (OHIP-14).

Furthermore, patients who had definitive IBFD for less than two months were not included in the study, to ensure that answers to the OHIP-14 are relevant.

2.2 Questionnaires and data collection

Two questionnaires have been submitted to patients.

The first is the OHIP-14 (figure 1). It assesses OHRQoL by measuring patients' perception of the social impact of oral disorders on their well-being, in the form of 14 questions covering 7 different subject matter fields: functional limitation; physical pain; psychological discomfort; physical disability; psychological disability; social disability; handicap. Responses were coded 0 = "never", 1 = "hardly ever",

2 = "occasionally", 3 = "fairly often" and 4 = "very often". Its score ranges from 0 (optimal quality of life) to 56 (very unsatisfactory quality of life) (24). For each of the 14 questions, patients were asked how frequently they had experienced the impact in the preceding weeks.

Figure 1: OHIP-14.

Functional limitation	Have you had trouble *pronouncing any words* because of problems with your teeth, mouth or dentures? Have you felt that your *sense of taste* has worsened because of problems with your teeth, mouth or dentures?
Physical pain	Have you had *painful aching* in your mouth? Have you found it *uncomfortable to eat any foods* because of problems with your teeth, mouth or dentures?
Psychological discomfort	Have you been *self-conscious* because of your teeth, mouth or dentures? Have you *felt tense* because of problems with your teeth, mouth or dentures?
Physical disability	Has your *diet been unsatisfactory* because of problems with your teeth, mouth or dentures? Have you had to *interrupt meals* because of problems with your teeth, mouth or dentures?
Psychological disability	Have you found it *difficult to relax* because of problems with your teeth, mouth or dentures? Have you been a bit *embarrassed* because of problems with your teeth, mouth or dentures?
Social disability	Have you been a bit *irritable with other people* because of problems with your teeth, mouth or dentures? Have you had *difficulty doing your usual jobs* because of problems with your teeth, mouth or dentures?
Handicap	Have you felt that life in general was *less satisfying* because of problems with your teeth, mouth or dentures? Have you been *totally unable to function* because of problems with your teeth, mouth or dentures?

A second questionnaire, designed by ourselves, was submitted to patients. This one allowed us to evaluate postoperative morbidity and patient satisfaction through the 6 following statements:

- “I had understood all the ins and outs of the intervention from which I benefited (notably risks inherent in the intervention and postoperative outcomes).”
- “I would have wished to benefit from this intervention even if I had known about the postoperative outcomes.”
- “Postoperative outcomes were not difficult to endure.”
- “The time to get my implant-borne fixed denture was short.”
- “I prefer my current oral comfort compared with my preoperative oral comfort.”
- “I do not regret having benefited from this surgery.”

To answer them, a Likert scale was proposed and responses were coded -2 = “Strongly disagree”, -1 = “Disagree”, 0 = “Neither agree nor disagree”,

+1 = “Agree” and +2 = “Strongly agree”. Its score ranges from -12 (serious postoperative morbidity and patient not satisfied) to +12 (no postoperative morbidity and patient very satisfied).

Implant/prosthetic survival rate and occurrence of potential per or postoperative complications were sought and noted in the medical record during the follow-up.

2.3 Surgical procedures: ABG followed by CI placement

Harvesting site was always parietal bone (figure 2).

Figure 2: Calvarial bone graft harvest (25) (Joël Ferri)**.**

Major alveolar bone loss in the sagittal plane may cause an inverted interarch relationship with dentoskeletal class III malocclusion (12). In such a case, LFIO associated with ABG was performed, for satisfying prosthesis function and aesthetics: after LFIO and detachment of the sinus membrane from the sinus floor, maxillary sinus was filled by scraped bone covered by bone plates fixed with titanium screws; then, after moving the maxilla forward and downward, osteosynthesis of the grafted maxilla was performed in the determined position according to the orthognathic and prosthodontic planning–a set-up was always carried out to simulate the final outcome (figure 3).

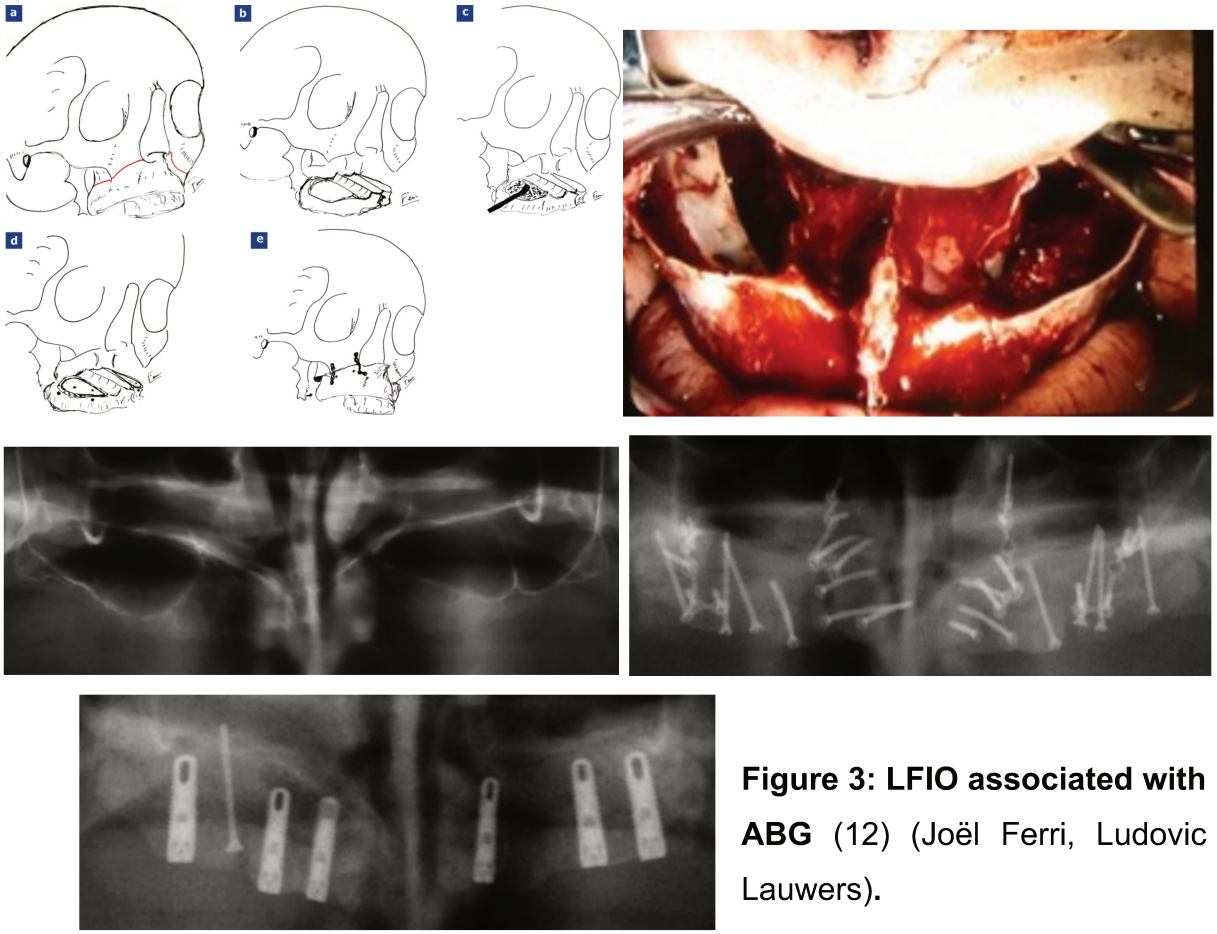


Figure 3: LFIO associated with ABG (12) (Joël Ferri, Ludovic Lauwers)**.**

Sinus lift realized by lateral approach was carried out if there was not inverted interarch relationship: an osteotomy on the lateral maxillary wall was done associated with an elevation of the sinus membrane and placement of bone graft.

When sinus lift realized by lateral approach was performed, onlay grafting was necessary: autogenous bone blocks were screwed on edentulous area, empty spaces were filled with particulate bone. In most cases, LFIO could allow to avoid onlay grafting in premaxilla area, horizontal advancement did indeed lead to the transfer of the newly generously grafted bicuspid area in the canine area.

CI placement was performed 6 months after surgery. Prosthetic steps began 6 months after this second surgery.

2.4 Surgical procedures: ZI placement

We placed 4 ZI if atrophy was generalized over the whole maxilla–severe lack of bone in zones I, II, and III according to Bedrossian (23), 2 ZI bilaterally (procedure

commonly known as “Quad Zygoma”). Their emergences were the lateral incisor or the canine site for the anterior ZI and the second premolar or the first molar site for the posterior ZI (figure 4).

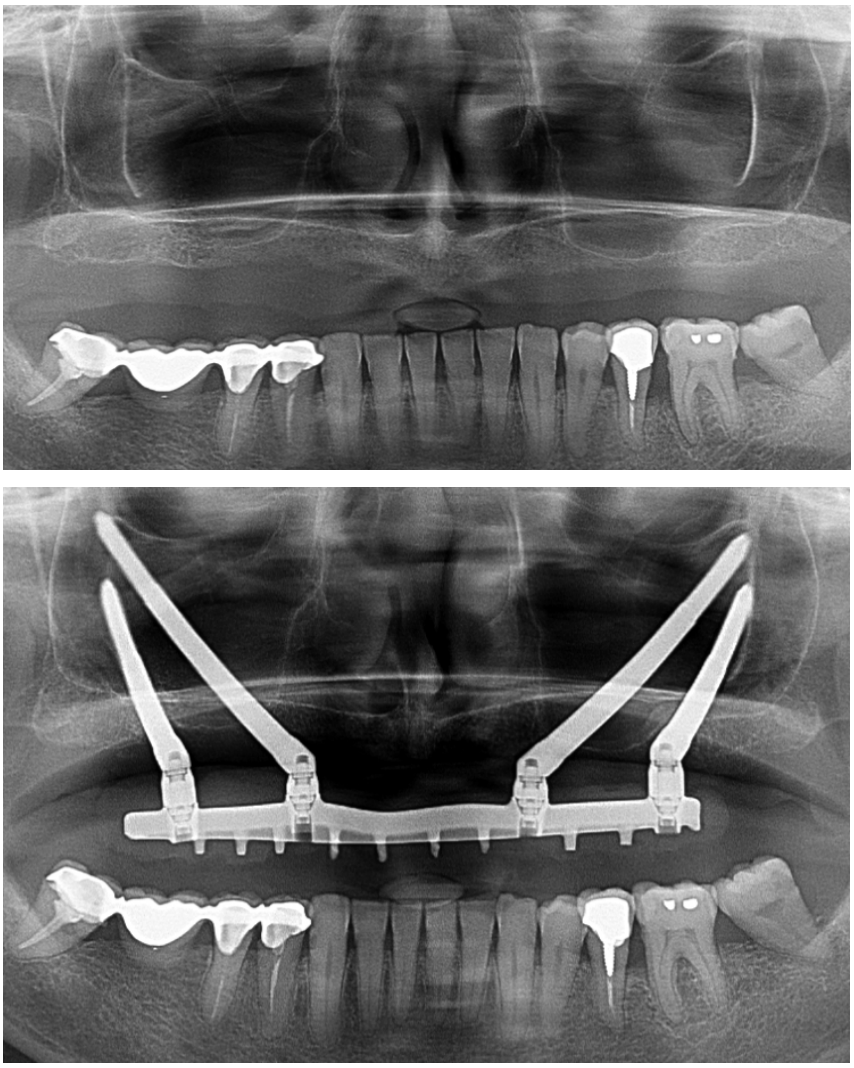


Figure 4: Management of an atrophic maxilla by 4 ZI placement (Gwénaël Raoul, Ludovic Lauwers)**.**

If there was sufficient bone quantity in zone I (premaxilla), 2 to 4 CI were placed in this area combined with 2 ZI placement emerging at the second premolar or the first molar site (procedure commonly known as “Hybrid Zygoma”).

Our current protocol was as follows: ridge incision–staying slightly palatal–associated with two buccal vertical releasing incisions on zygomaticomaxillary buttress; elevation of a mucoperiosteal flap highlighting zygomatic bones, infraorbital foramina, infraorbital margins and nasal fossae; crestal bone reduction if necessary according to evaluation of patient’s smile line in order to prevent any future visibility of the transition zone between prothesis and native gingiva; maxillary sinus antrostomy; elevation of the sinus membrane making an effort to not damage it; implant drilling

sequence from the palate trying to have a ridge of bone around ZI's head if the anatomic ridge was not too palatal, otherwise drilling was performed from the top of the crest without anchorage in that area allowing a position of the ZI's head near the ideal prosthetic position; implants placement with a minimum insertion torque of 35 N/cm^2 and abutments placement; impression copings placement; sutures; open tray impression; healing caps placement (figure 5).

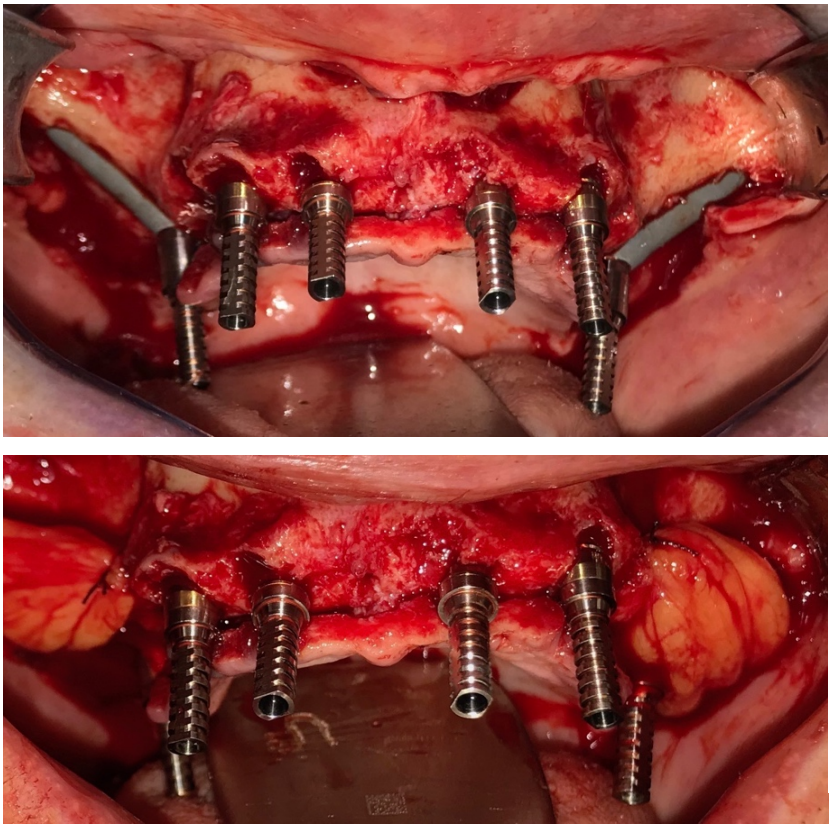


Figure 5: 2 ZI + 4 CI placement, abutments and impression copings are screw-retained, buccal fat pads are transposed to cover ZI (Gwénaël Raoul, Ludovic Lauwers, Alexandre Laventure)**.**

2.5 Prosthetic rehabilitation

When ABG followed by CI placement were carried out, permanent IBFD–made of porcelain or acrylic resin fused to metal or all-ceramic–was performed 6 months after implants placement. Artificial gingiva could be used or not, it depended on the smile line, the transition zone between natural and artificial gingiva should never be visible.

In the case of ZI placement, an acrylic resin temporary IBFD was trans-screwed on the day or the next day of surgery. A metal-acrylic resin or metal-ceramic permanent IBFD was performed 6 months after. Artificial gingiva was always used for

these dentures. Whenever natural gingiva was visible when patient forced a maximum smile during preoperative clinical examination, bone reduction was performed to avoid visibility of the transition zone between natural and artificial gingiva when smiling.

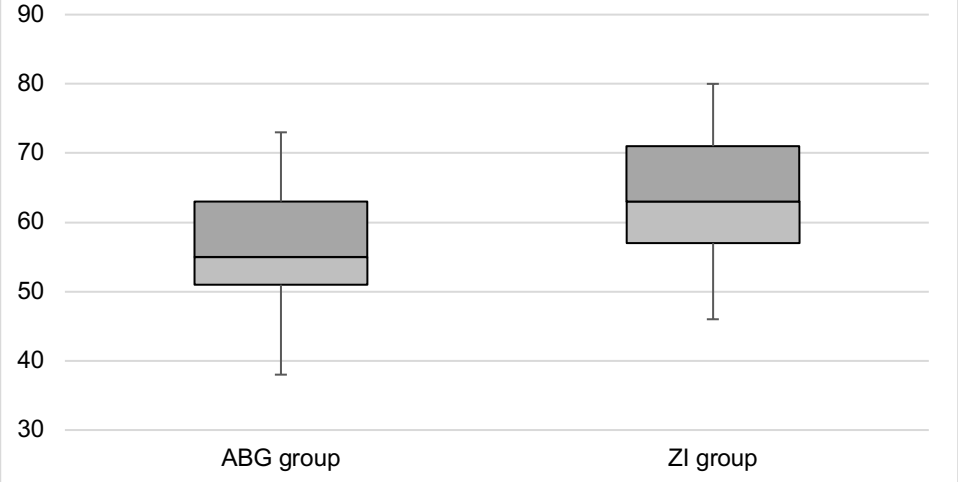
2.6 Statistical analysis

Qualitative parameters were described in terms of frequency and percentage. Numerical parameters were described in terms of median and interquartile range (IQR). Normality of these numerical parameters was verified graphically and tested using the Shapiro-Wilk test. Inclusion patient characteristics and outcomes were compared between groups using a Fisher's test for qualitative variables and a Mann-Whitney U test for numerical variables. Univariate significant associations between numerical outcomes and groups were adjusted for age using a linear regression model. Level of significance was set at 5%. SAS statistical software (version 9.4) was used to analyze the data (SAS Institute, Cary, NC).

3. Results

Forty-three patients were included in the study (21 patients in the ABG group, 22 patients in the ZI group): 33 females and 10 males, aged from 38 to 73 years old when ABG was performed with a median age of 55.0 years old (IQR: 51.0; 63.0), aged from 46 to 80 years old when ZI placement was performed with a median age of 63.0 years old (IQR: 57.0; 71.0). Concerning the age, there was a statistically significant difference between groups with a Wilcoxon signed-rank test (*p*-value = 0.013) (figure 6).

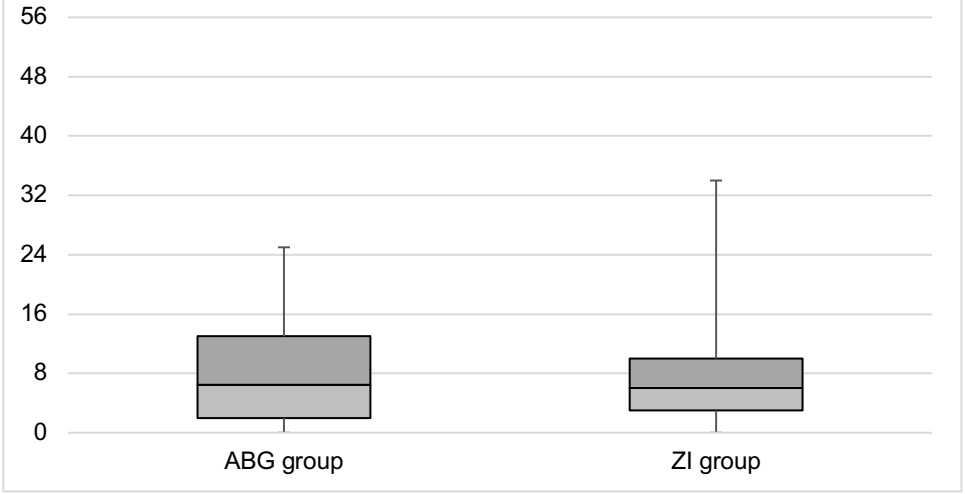
Figure 6: Patient age



Five patients included in the ZI group benefited in our department from ABG which failed: early bone graft resorption preventing CI placement in 1 patient, severe peri-implant bone loss in 4 patients (attributed to a peri-implantitis in 1 patient). One patient preferred to stick with her removable denture after an ABG failure.

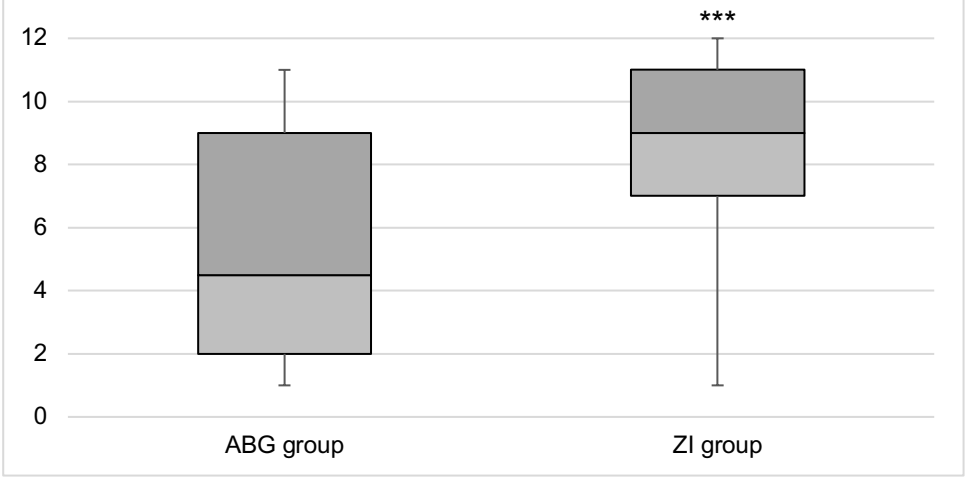
In the ABG group, OHIP-14 median score was 6.5 (IQR: 2.0; 13.0). In the ZI group, it was 6.0 (IQR: 3.0; 10.0). There was no statistically significant difference between groups with a Wilcoxon signed-rank test (*p*-value = 0.97) (figure 7).

Figure 7: OHIP-14 score



In the ABG group, postoperative morbidity and patient satisfaction median score was 4.5 (IQR: 2.0; 9.0). In the ZI group, it was 9.0 (IQR: 7.0; 11.0). There was a statistically significant difference between groups with a Wilcoxon signed-rank test (*p*-value = 0.003) (figure 8). Even taking into account the age of the patients, scores remain significantly different with *p*-value = 0.004. Better results for the ZI group are explained by highest median score to the 3rd statement (postoperative outcomes) and the 4th one (time to get an IBFD) which was 1 and 2 respectively *vs* 0 and 0 in the ABG group (table 3).

Figure 8: Postoperative morbidity and patient satisfaction score

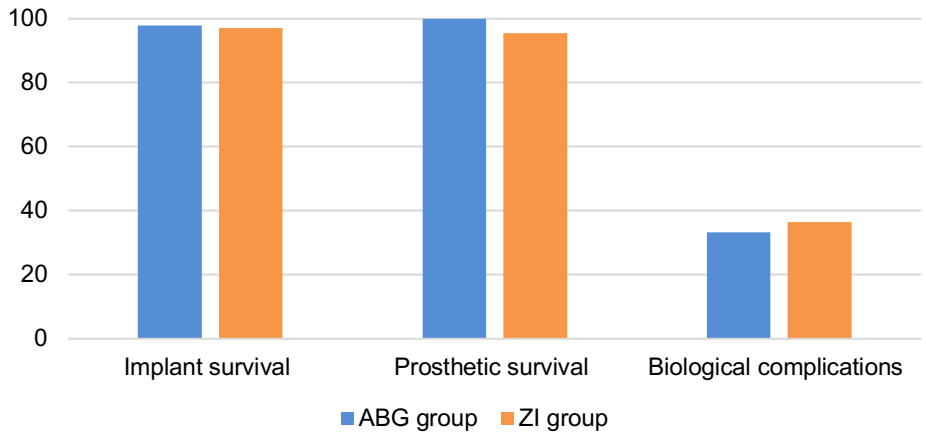


In the AGB group, 3 patients lost 3 implants, overall implant survival rate was of 97.9% and prosthetic survival rate was of 100%. In the ZI group, 2 patients lost 3

implants (1 CI in one patient, 2 ZI in the other), the IBFD had to be removed in the patient who lost 2 ZI, survival rates were of 97.1% and 95.5% respectively (figure 5); overall zygomatic implant survival rate was of 97.3% (not counting conventional implants loss).

In the ABG group, biological complications rate was of 33.3%. In the ZI group, it was 36.4% (figure 9); not counting biological complications linked with conventional implants, it was 31.8%. There was no statistically significant difference between groups with a chi-square test (*p*-value = 0.83). In the AGB group, biological complications were: ABG failure preventing CI placement, peri-implantitis, osseointegration failure or sinusitis. In the ZI group, they were: mucositis, osseointegration failure, sinusitis, dysesthesia or soft tissues recession.

Figure 9: Implant/prosthetic survival and biological complications rates



All of these biological complications have been managed and resolved successfully except one dysesthesia without etiology found. ABG failure was resolved by ZI placement, peri-implantitis by a conservative treatment, osseointegration failures by a therapeutic abstention if prosthetic biomechanical conditions allowed or by a replacement of the failed implants by new ones, sinusitis by medical or surgical treatment, mucositis by hygiene maneuvers, and the dysesthesia linked with soft tissue recession by a buccal fat pad transposition.

Patients' data have been listed in table 1. OHIP-14 scores in detail have been listed in table 2. Postoperative morbidity and patient satisfaction scores in detail have been listed in table 3. Indications and length of follow-up have been listed in table 4; concerning questionnaires responses, length of follow-up represents the time

elapsed between implants placement and the date the patient replied to the questionnaires.

Table 1: Patients' data

Patient	Group	Age	CI placed	ZI placed	CI lost	ZI lost	Prosthetic survival	Biological complications	OHIP-14 score	Postoperative morbidity and patient satisfaction score
1	ABG	45	6		0		1	Peri-implantitis on one implant	21	9
2	ABG	59	0					ABG failure, didn't want ZI, preferred to stick with her removable denture		
3	ABG	63	8		0		1	Unilateral sinusitis, resolved by surgical treatment	14	9
4	ABG	61	8		0		1	0	0	5
5	ABG	65	5		0		1	0	0	9
6	ABG	52	8		0		1	0	11	10
7	ABG	52	8		0		1	0	1	9
8	ABG	51	8		0		1	0	19	4
9	ABG	55	8		0		1	0	14	1
10	ABG	56	7		0		1	0	25	1
11	ABG	51	6		1		1	Loss of one CI	9	4
12	ABG	63	8		1		1	0	0	8
13	ABG	73	6		0		1	Unilateral paresthesia	5	3
14	ABG	38	8		0		1	Unilateral sinus mucocele	6	1
15	ABG	55	6		0		1	0	2	7
16	ABG	71	6		0		1	0	3	1
17	ABG	44	6		0		1	0	3	7
18	ABG	68	8		0		1	0	8	11
19	ABG	56	8		0		1	0	7	4
20	ABG	53	8		0		1	0	2	3
21	ABG	40	8		1		1	Loss of one CI	12	1
22	ZI	80	2	2	1	0	1	Loss of one CI (no osseointegration), replacement just after removal	3	9
23	ZI	57	3	3	0	0	1	0	3	
24	ZI	66	4	2	0	0	1	Mucositis around one ZI	6	12
25	ZI	46	0	4		0	1	0	2	
26	ZI	63	0	4		0	1	Mucositis around one ZI	0	
27	ZI	54	0	4		0	1	0	1	11
28	ZI	63	4	2	0	0	1	Unilateral sinusitis, resolved by surgical treatment	9	9
29	ZI	72	0	4		0	1	0	4	11
30	ZI	52	0	4		0	1	0	11	10
31	ZI	66	0	4		0	1	0	8	9
32	ZI	57	4	2	0	0	1	0	0	12

Patient	Group	Age	CI placed	ZI placed	CI lost	ZI lost	Prosthetic survival	Biological complications	OHIP-14 score	Postoperative morbidity and patient satisfaction score
33	ZI	57	0	4		0	1	0	4	7
34	ZI	63	4	2	0	0	1	Bilateral sinusitis, resolved by medical treatment	8	9
35	ZI	71	4	2	0	0	1	0	19	1
36	ZI	55	0	4		0	1	0	34	5
37	ZI	65	0	4		0	1	Unilateral dysesthesia	10	6
38	ZI	74	4	2	0	0	1	0	5	11
39	ZI	76	0	4		2	0	Loss of two ZI	14	6
40	ZI	71	0	4		0	1	0	11	12
41	ZI	68	0	4		0	1	0	3	11
42	ZI	57	0	4		0	1	0	10	11
43	ZI	59	0	4		0	1	Unilateral dysesthesia with soft tissue recession	6	9

Table 2: OHIP-14 scores in detail

Patient	Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
1	ABG	2	1	1	1	3	3	2	1	1	1	0	2	3	0	21
2	ABG															
3	ABG	3	0	1	1	2	2	0	0	2	0	1	0	2	0	14
4	ABG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	ABG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	ABG	0	0	0	1	0	3	3	0	0	0	0	2	0	2	11
7	ABG	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
8	ABG	3	0	2	2	2	0	2	0	2	2	2	0	1	1	19
9	ABG	3	2	3	3	4	2	1	2	2	2	0	2	2	1	14
10	ABG	4	3	0	2	3	0	0	2	1	2	0	3	3	2	25
11	ABG	1	0	2	0	0	3	0	0	0	1	2	0	0	0	9
12	ABG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	ABG	0	0	0	0	0	0	3	0	0	2	0	0	0	0	5
14	ABG	4	0	2	0	0	0	0	0	0	0	0	0	0	0	6
15	ABG	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
16	ABG	2	0	0	0	0	1	0	0	0	0	0	0	0	0	3
17	ABG	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
18	ABG	4	0	0	0	0	0	0	0	2	2	0	0	0	0	8
19	ABG	0	0	2	0	0	0	0	0	2	2	0	1	0	0	7
20	ABG	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
21	ABG	4	1	1	0	0	1	0	0	0	2	0	3	0	0	12
22	ZI	0	0	0	2	0	0	0	0	0	1	0	0	0	0	3
23	ZI	1	0	1	0	0	0	0	0	1	0	0	0	0	0	3
24	ZI	1	0	1	1	0	1	0	0	0	1	0	0	1	0	6
25	ZI	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2
26	ZI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	ZI	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
28	ZI	1	0	2	1	1	0	1	1	1	0	0	0	1	0	9
29	ZI	1	0	1	1	0	0	1	0	0	0	0	0	0	0	4
30	ZI	0	2	0	2	1	1	1	0	2	2	0	0	0	0	11
31	ZI	3	0	0	3	0	0	2	0	0	0	0	0	0	0	8
32	ZI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	ZI	3	0	1	0	0	0	0	0	0	0	0	0	0	0	4
34	ZI	0	2	0	2	0	2	0	0	0	2	0	0	0	0	8
35	ZI	2	2	2	1	2	2	1	0	2	1	3	1	0	0	19
36	ZI	4	0	0	4	4	0	3	0	2	4	2	4	4	3	34
37	ZI	3	0	3	0	1	0	0	1	0	0	2	0	0	0	10
38	ZI	3	0	0	0	2	0	0	0	0	0	0	0	0	0	5
39	ZI	2	0	2	1	2	3	1	0	0	2	1	0	0	0	14
40	ZI	2	1	0	2	0	2	1	1	2	0	0	0	0	0	11
41	ZI	0	0	1	0	0	2	0	0	0	0	0	0	0	0	3
42	ZI	3	0	0	0	3	0	0	0	2	0	0	2	0	0	10
43	ZI	0	0	0	0	2	0	0	0	0	0	0	2	0	2	6

Table 3: Postoperative morbidity and patient satisfaction scores in detail

Patient	Group	1	2	3	4	5	6	Total
1	ABG	1	2	2	1	1	2	**9**
2	ABG							
3	ABG	2	1	1	1	2	2	**9**
4	ABG	2	1	-2	0	2	2	**5**
5	ABG	2	2	1	1	1	2	**9**
6	ABG	2	2	1	1	2	2	**10**
7	ABG	2	2	1	0	2	2	**9**
8	ABG	2	2	-2	-2	2	2	**4**
9	ABG	1	0	-2	-2	2	2	**1**
10	ABG	-1	1	-2	1	1	1	**1**
11	ABG	1	1	1	-1	1	1	**4**
12	ABG	2	1	2	0	1	2	**8**
13	ABG	-1	1	1	-1	2	1	**3**
14	ABG	1	1	-1	-1	0	1	**1**
15	ABG	2	2	1	-2	2	2	**7**
16	ABG	0	1	-2	-2	2	2	**1**
17	ABG	2	2	-1	0	2	2	**7**
18	ABG	2	2	2	1	2	2	**11**
19	ABG	0	2	-2	0	2	2	**4**
20	ABG	1	2	-1	-2	1	2	**3**
21	ABG	0	1	-2	-2	2	2	**1**
22	ZI	1	1	1	2	2	2	**9**
23	ZI							
24	ZI	2	2	2	2	2	2	**12**
25	ZI							
26	ZI							
27	ZI	2	1	2	2	2	2	**11**
28	ZI	1	1	2	2	2	1	**9**
29	ZI	2	2	1	2	2	2	**11**
30	ZI	2	1	1	2	2	2	**10**
31	ZI	2	2	2	-1	2	2	**9**
32	ZI	2	2	2	2	2	2	**12**
33	ZI	2	2	-1	1	1	2	**7**
34	ZI	1	2	2	2	0	2	**9**
35	ZI	0	0	1	-1	1	0	**1**
36	ZI	1	2	2	-2	0	2	**5**
37	ZI	0	-1	1	2	2	2	**6**
38	ZI	1	2	2	2	2	2	**11**
39	ZI	1	0	-1	2	2	2	**6**
40	ZI	2	2	2	2	2	2	**12**
41	ZI	2	2	1	2	2	2	**11**
42	ZI	2	2	1	2	2	2	**11**
43	ZI	1	2	1	2	1	2	**9**

Table 4: Indications and length of follow-up

Patient	Group	Indication	Length of follow-up	
			Implant survival, biological complications	Questionnaires responses
1	ABG	Total edentulism	6 yrs 7 mos	6 yrs 7 mos
2	ABG	Total edentulism, removable denture		
3	ABG	Partial edentulism, non-restorable remaining teeth	3 yrs 9 mos	6 yrs 2 mos
4	ABG	Severe periodontitis	0 yr 8 mos	6 yrs 0 mo
5	ABG	Non-restorable remaining teeth	0 yr 8 mos	5 yrs 10 mos
6	ABG	Total edentulism, maxillofacial trauma sequelae	2 yrs 11 mos	6 yrs 6 mos
7	ABG	Severe periodontitis	1 yr 0 mo	6 yrs 5 mos
8	ABG	Non-restorable remaining teeth	1 yr 2 mos	3 yrs 8 mos
9	ABG	Total edentulism, removable denture	3 yrs 8 mos	3 yrs 6 mos
10	ABG	Subtotal edentulism	4 yrs 6 mos	4 yrs 7 mos
11	ABG	Total edentulism	4 yrs 6 mos	4 yrs 5 mos
12	ABG	Total edentulism	3 yrs 3 mos	4 yrs 4 mos
13	ABG	Severe periodontitis	3 yrs 0 mo	2 yrs 9 mos
14	ABG	Total edentulism	3 yrs 0 mo	2 yrs 6 mos
15	ABG	Total edentulism	3 yrs 6 mos	2 yrs 11 mos
16	ABG	Subtotal edentulism	1 yr 10 mos	1 yr 5 mos
17	ABG	Partial edentulism, non-restorable remaining teeth	1 yr 1 mo	1 yr 5 mos
18	ABG	Subtotal edentulism	1 yr 9 mos	2 yrs 0 mo
19	ABG	Partial edentulism, severe periodontitis	1 yr 0 mo	2 yrs 2 mos
20	ABG	Partial edentulism, severe periodontitis	1 yr 2 mos	1 yr 6 mos
21	ABG	Subtotal edentulism	1 yr 2 mos	1 yr 9 mos
22	ZI	Subtotal edentulism, removable denture	8 yrs 7 mos	7 yrs 5 mos
23	ZI	Total edentulism, removable denture, ABG failure	1 yr 3 mos	7 yrs 2 mos
24	ZI	Severe periodontitis	6 yrs 1 mo	5 yrs 7 mos
25	ZI	Total edentulism, peri-implant bone loss 2 yrs after ABG (immunosuppressive therapy for Crohn's disease)	4 yrs 4 mos	5 yrs 5 mos
26	ZI	Subtotal edentulism, peri-implant bone loss 1 yr after ABG	5 yrs 9 mos	5 yrs 4 mos
27	ZI	Total edentulism, ABG 12 yrs ago, peri-implantitis	5 yrs 10 mos	5 yrs 5 mos
28	ZI	Partial edentulism, severe periodontitis	4 yrs 0 mo	3 yrs 9 mos
29	ZI	Partial edentulism, non-restorable remaining teeth	2 yrs 7 mos	3 yrs 3 mos
30	ZI	Total edentulism, removable denture, peri-implant bone loss less than a yr after ABG	2 yrs 6 mos	2 yrs 11 mos
31	ZI	Subtotal edentulism	2 yrs 11 mos	2 yrs 9 mos
32	ZI	Total edentulism	0 yr 7 mos	1 yr 11 mos
33	ZI	Partial edentulism, severe periodontitis	2 yrs 3 mos	1 yr 6 mos
34	ZI	Loss of bone around existing implants, non-restorable remaining teeth	1 yr 10 mos	1 yr 4 mos
35	ZI	Subtotal edentulism	1 yr 7 mos	1 yr 4 mos
36	ZI	Total edentulism, removable denture	1 yr 8 mos	1 yr 11 mos
37	ZI	Loss of bone around existing implants	1 yr 11 mos	1 yr 3 mos
38	ZI	Partial edentulism, severe periodontitis	1 yr 6 mos	1 yr 2 mos
39	ZI	Loss of bone around existing implants	1 yr 7 mos	1 yr 10 mos
40	ZI	Partial edentulism, non-restorable remaining teeth	1 yr 1 mo	9 mos
41	ZI	Partial edentulism, non-restorable remaining teeth	0 yr 10 mos	9 mos
42	ZI	Total edentulism, removable denture	1 yr 1 mo	9 mos
43	ZI	Total edentulism, removable denture	0 yr 9 mos	8 mos

4. Discussion

4.1 About ABG followed by CI placement

In the literature, two studies compare clinical outcomes and postoperative quality of life of bone augmentation with xenogenous bone substitutes followed by CI placement *vs* immediate loaded ZI placement for the fixed rehabilitation of the atrophic edentulous maxilla. These two studies have been conducted by the same authors, one provides 4-month results (26), the other provides 1-year results (27). The major different with our study is grafting protocol. We only used autogenous bone taken from calvarial.

Autogenous bone is widely regarded as the gold standard technique for ABG, being the only possessing osteogenic, osteoconductive and osteoinductive properties (28).

In the literature, use of xenogenous, allogenous or alloplastic bone substitutes is currently under-documented for reconstruction of an atrophic edentulous maxilla, especially for alveolar ridge augmentations, contrary to sinus augmentation for which these materials already proven their worth (29). A few studies about alveolar ridge augmentation with bone substitutes exist but must of them lake power, sample is small, their length of follow-up is short and/or success implant rate is not specified (30) (31) (32). By contrast, ABG procedures are widely documented, whether on isolated alveolar bridge augmentations or on complete reconstructions of atrophic maxillae, with large series of tens of patients and several years long-term follow-ups associated with success rates exceeding 95% even when major augmentation procedures had to be carried out for severely resorbed jaws (33) (9) (10) (11) (34) (19) (35).

Another positive aspect of ABG is healing time: 3 to 6 months of healing are necessary whereas bone substitutes require more than 6 months of healing in the best-case scenario (35). Thus, we believe that bone substitutes procedures do not appear to be well suited for treatment of atrophic maxillae.

Concerning the harvesting site, parietal bone remains the best leading to very good results associated with no serious complications, low bone resorption and a

high implant osseointegration rate, and considering the amount of available bone fully suited for atrophic maxillae reconstructions (25). Intraoral donor sites are not adapted given the extent of graft to carry out. Furthermore, this procedure is associated with lower morbidity compared to iliac crest bone harvest, postoperative course is simple and surgical recovery is faster (36) (37).

In our study, in all cases of ABG except two, LFIO was performed. Indeed, residual ridge resorption is centripetal in maxilla and centrifugal in mandible, these processes create in most of the cases a real inverted interarch relationship with class III malocclusion (38).

LFIO associated with ABG remains the preferred technique in case of anterior dental gap to restore dentoskeletal class I normoclusion and minimize the amount of graft placed or at best avoid onlay grafting in premaxilla area where resorptions may be important (10), thanks to the horizontal advancement leading to the transfer of the newly generously grafted bicuspid area in the canine area. It also allows to reduce an excessive prosthetic space by lowering the position of the palatal plate. Thus, this procedure can allow to avoid anterior and posterior onlay grafting, which can be prone to resorption mainly because of the situation of the incision located close to the graft site leading to an exposure caused by a vascularization failure (39), unlike LFIO procedure involving a vestibular incision. Furthermore, intrasinus grafts are not subject to muscular pressure from the soft tissues by contrast with onlay grafts for alveolar ridge augmentation.

We placed 6 to 8 CI if bone volumes permitted it. Literature shows that a denture can be screwed on 4 CI in the maxilla (40), but it is recommended placing 6 implants whenever possible. Indeed, in their study, Brånemark et al. show that there is a significantly increased risk to lose one or more implants when only 4 instead of 6 are placed to support an IBFD; the situation can become complex to manage if one of the 4 implants is lost, forcing the practitioner to plan a new surgical intervention to reach the minimum number of abutments on the arch (41).

ABG permits reconstruction of the atrophic maxilla from the posterior maxilla to the premaxilla, allowing a distribution of 6 to 8 CI well along the curvature of the occlusal line, which is a key criterion of the success according to Rangert (42).

The most feared complication is the failure of the surgery associated with early bone graft resorption preventing CI placement or late resorption causing a peri-implant bone loss. Early resorption occurred in 3 patients of our sample

modifying the treatment plan: one benefited from 3 ZI with 3 CI placement, one benefited from 5 CI placement not impeding the installation of an IBFD, and one kept his removable denture. Severe peri-implant bone loss occurred on 4 patients (attributed to a peri-implantitis in 1 patient), who subsequently benefited from 4 ZI placement. No complication occurred at the donor site. Our implant survival rate is comparable or slightly better to other studies (8) (33) (12) (20). Compared to the results of Davó's study (27), our prosthetic survival rate is higher and our biological complications rate is comparable but slightly lower.

Reconstruction of the whole maxilla followed by CI placement without compromise also allows to avoid cantilevers which can double the stress on distal implants increasing risk of failure (43).

Restoration of correct interarch relationships in the sagittal/frontal/transverse planes associated with the control of smile line and gingival display by LFIO allows to make an IBFD without artificial gingiva replacing only the anatomical crowns of the missing natural teeth and appearing to the patient to be similar to crowns on natural teeth, prosthetic crowns height is sufficient for satisfying prosthesis function and aesthetics. This is a FP-1 restoration according to Misch (44). These bridges meet the patient's requirements for esthetics, hygiene maintenance (thanks to hygiene maneuvers similar to natural teeth), phonetics and comfort related to the absence of artificial gingiva making them not cumbersome (45) (46) (figure 10).

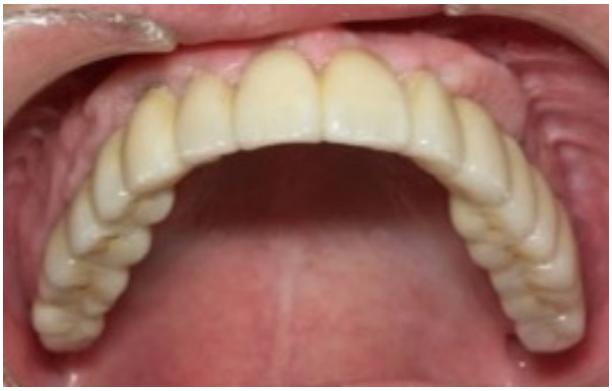


Figure 10: FP-1 all-ceramic restoration (Ludovic Lauwers)**.**

For this kind of restauration, implants must be perfectly positioned facing prosthetic crowns in a location similar to the root of a natural tooth to allow hygiene maneuvers by the patient and to avoid an implant position between two teeth or too buccal or palatal causing an aesthetic issue on the prosthesis.

The major drawback of this kind of restauration is soft tissue management linked with the difficulty keeping interdental papillae and potentially causing the presence of black triangular spaces when the patient smiles. In this case, some artificial gingiva can be added on cervical border to mimic soft tissues, but there will be consequences to the aesthetics if natural gingiva is displayed during smiling.

4.2 About ZI

If atrophy was generalized over the whole maxilla, 4 ZI were placed (Quad Zygoma). If there was sufficient bone quantity in the premaxilla, 2 to 4 CI were placed in this area–4 if bone volumes permitted it–combined with 2 posterior ZI (Hybrid Zygoma).

Brunski explains that the masticatory forces are better distributed on a prosthesis fixed on 6 implants instead of 4, thus reducing the risk of prosthetic fracture, biomechanical stress on each implant is less important in this situation (47).

Furthermore, when we performed ZI placement, we try to ensured distal ones emerged at the first molar site to avoid prosthetic cantilevers, distalization of the implant platform reducing the moments of force and improving the load distribution (48) (49). A greater length of distal cantilever of the IBFD can increase the stress on the distal implants and the risk of prosthetic fracture (50) (51). However, the literature describes high implant and prosthetic survival rates in patients with a cantilevered IBFD even with a two-teeth distal cantilever in the prosthesis (52).

Therapeutic approach is different compared with bone grafting procedures. When we proposed this graftless solution to patients, we knew that interarch relationships in the sagittal/frontal/transverse planes would be restored by prosthetics. In fact, in our patients, vertical dimension, crown height space and lip support were always managed by a FP-3 restauration (44), whose the concept was initially described by Brånemark (53). Likewise, sagittal and transverse skeletal discrepancies were offset by an angulation of artificial gingiva of never more than 45° not to compromise lip movements when smiling and to avoid food impaction in transition zone between artificial and natural gingiva (54).

For this kind of restoration, implants are placed to distribute masticatory forces harmoniously on the arch allowing an implants placement less stringent compared

with FP-1 restauration. Added to this, an unfavorable implant emergence or off-axis placement are corrected by angled or straight abutments placement which also make hygiene maneuvers easier by situating the implant connection just at level of the gingival surface. The aesthetic finish is very good thanks to artificial gingiva which mimics soft tissues (figure 11).

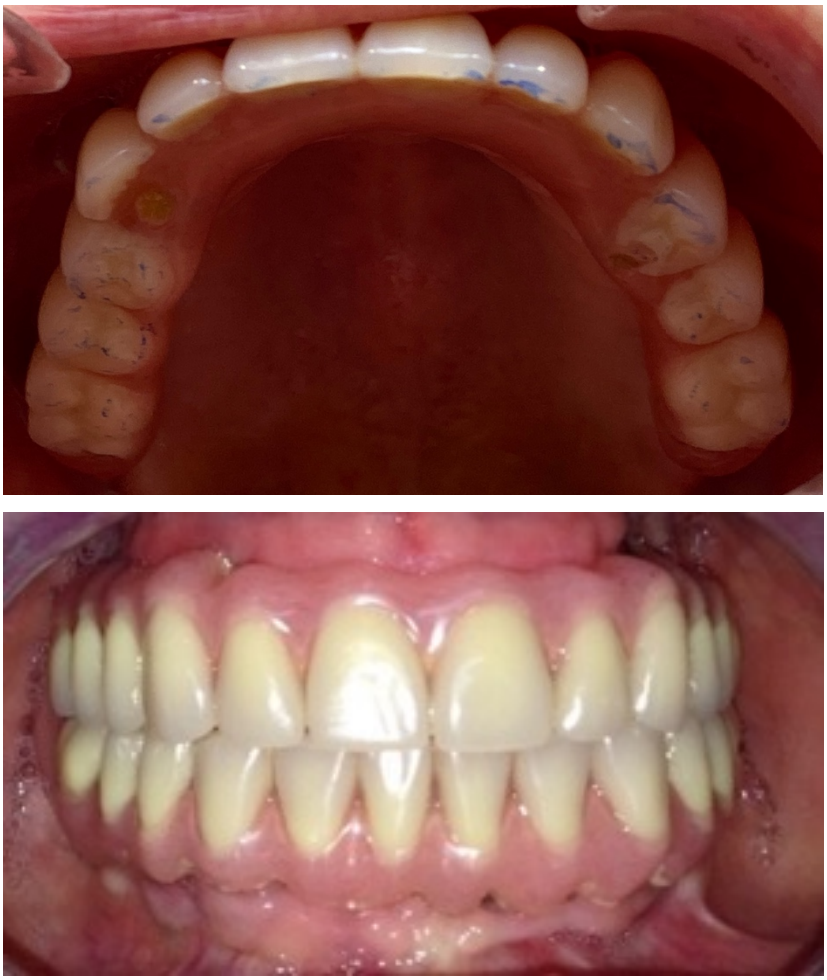
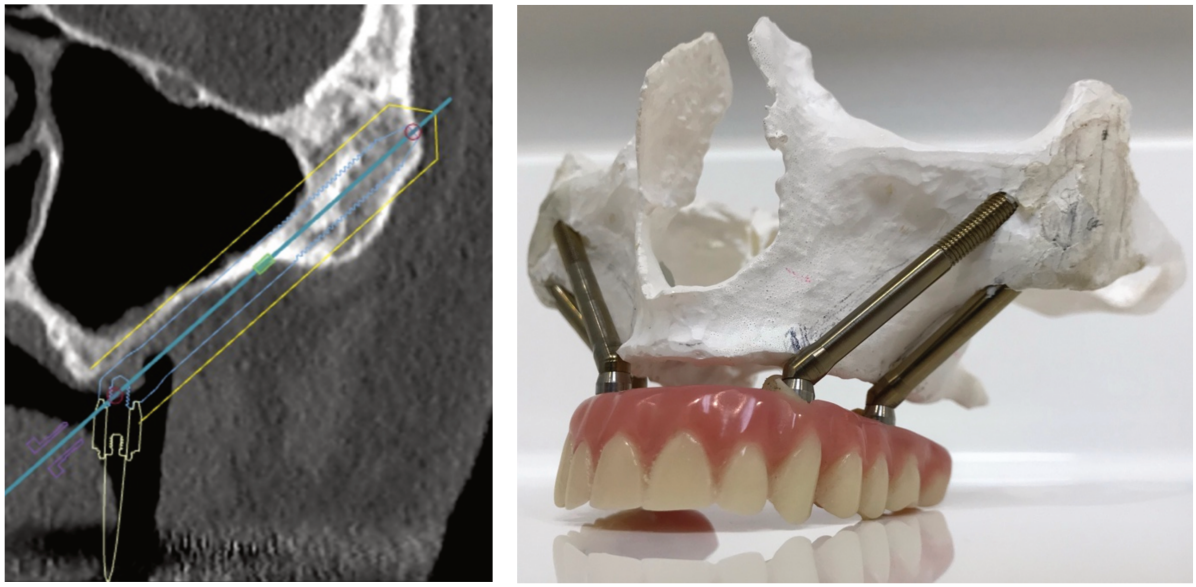


Figure 11: FP-3 provisional restauration after 4 ZI placement (Ludovic Lauwers)**.**

Palatine emergence of ZI can lead to complications–such as periimplantitis potentially causing sinusitis–related to hygiene maneuvers difficult to achieve. These ones are greatly facilitated thanks to the “extramaxillary surgical technique” (54) also known as “extrasinus placement” (55) allowing a position of the ZI’s head in the prosthetic corridor near the ideal prosthetic position, at the center of the ridge crest and less palatal compared with the first surgical protocol described by Brånemark (56), such that the ZI’s body is buccal and outside of any maxillary bony housing. It also allows the fabrication of a prosthesis significantly less cumbersome

thanks to the position of the ZI emergences near the buccal side of the residual crest (figures 12 and 13).



Figures 12 and 13: Extramaxillary approach (Gwénaël Raoul)**.**

This extramaxillary surgical technique is associated with very high implant and prosthetic survival/success rates minimizing the risk of sinusitis thanks to an easier elevation without perforation of the sinus membrane (14) (55), no sinusitis was moreover noted in our last patients treated with this technique. A complication of this technique is vestibular exposure of ZI by a gingival recession linked with thin and fragile periodontal biotype or caused by mucositis; however this complication can be prevent by buccal fat pad transposition to cover the ZI for thickening peri-implant tissues (57).

Our implant survival rate is comparable to other studies and our biological complications rate is higher compared to the results of other studies, but as discussed by Chrcanovic in his systematic review, prevalence of complications could be underestimated in the literature because several publications did not report their presence or absence (15). Compared to the results of Davó's study (27), our prosthetic survival rate is comparable and our biological complications rate is lower.

Our prosthetic protocol was as follows: an acrylic resin IBFD provisionally, then a metal-acrylic resin or a metal-ceramic IBFD 6 months after. Metal-ceramic was chosen as a first choice for cosmetic reasons in patients who were not suspected of being heavy bruxers and if there was not ceramic denture in the opposing arch.

Probability of crown fractures is indeed increased in patients with bruxism habits (58) and in patients who present ceramic dentures on the two arches (59).

4.3 About comparison between the two procedures

Our results of the OHIP-14 leads up to think that OHRQoL is the same whether choosing ZI procedure or ABG followed by CI placement. Nevertheless, the sample size was relatively small and the statistical power has not been evaluated due to the retrospective design of the study, preventing us from really recording absence of difference between the two groups. In their 1-year follow-up study, Davó et al. have not highlighted statistically significant differences either and our OHIP-14 scores are comparable to theirs (27) or to other studies (60) (18) (61), and slightly better as those reported by Misumi et al. (62).

In both cases, our results are very satisfactory given that a German study had found OHIP-14 scores ranging from 0 to 11 for subjects without dentures (63).

Considering results of our Likert questionnaire evaluating postoperative morbidity and patient satisfaction, we may concede that ABG procedure has greater morbidity compared with ZI procedure. This is not surprising, given that ABG is a more invasive surgery, especially when a LFIO is performed, while also knowing that two surgeries are needed before prosthetic procedures–ABG then CI placement–and additional surgical site is required for ABG thus another potential location for postoperative pain and complications.

Furthermore, atrophic maxilla contributes to an increased risk during LFIO (64), even if such complications was not encountered in our sample.

Risk of bone fracture during ZI placement also exists, we have experienced it in one patient in whom zygomatic bone thickness was low. Zygomatic bone fracture was treated by osteosynthesis using parietal bone graft (initially scheduled to close a large oroantral fistula) to increase bone width. ZI were placed at the same surgical time. Unfortunately, osseointegration failure occurred in distal ZI, it was replaced after a healing period of 4 months, without complications. This patient, still undergoing treatment with a provisional prosthesis, was thus not included in our study. A very high insertion torque–which is common with ZI–combined with a thin zygomatic bone would increase risk of fracture.

ZI placed under local anesthesia with or without intravenous sedation is an option when surgical complexity is relatively low, which is particularly the case of Hybrid Zygoma, however this procedure is recommended only if the surgeon is experienced and when patient compliance is high (65).

FP-3 restorations performed after ZI placement can be considered as more cumbersome compared with FP-1 ones, however our OHIP-14 scores suggest that there is no impact or difference between two groups. Furthermore, we may think that hygiene is more difficult to control due to the implant-prosthetic connection located more apically compared with FP-1 restorations, but good hygiene education allows to prevent any maintenance problems (66). FP-3 restorations are a good prosthetic solution for edentulous patients, the strong point is gingival aesthetics which is easily controlled thanks to artificial gingiva. Nevertheless, great care must be taken that transition zone between natural and artificial gingiva is not visible when smiling. In some cases, bone reduction had to be done before ZI placement to hide the future transition zone.

Taking all these elements into account, immediate loaded ZI placement seems to be a first-line therapeutic option for the fixed rehabilitation of the atrophic edentulous maxilla. In support of this position, we note that our implant/prosthetic survival rates and biological complications rate are similar between the two groups.

However, we think that certain clinical situations still require LFIO associated with ABG as a first choice. First situation is major class III skeletal discrepancy which could not be offset by an angulation of artificial gingiva sufficient to allow satisfying prosthesis function and aesthetics. Second situation is the presence of large oroantral fistula often associated with chronic sinusitis. We already encountered this situation in patients with serious maxillary sequelae of previous sinus grafting with biomaterial. We used to cure this complication with this procedure allowing sinus curettage, oroantral fistula closing and bone reconstruction in a single operation (67). Third situation is patients with anodontia, these patients very often have insufficient bone volumes for implants placement due to the absence of alveolar growth related to the absence of dental organs, orthognathic surgery is required as facial growth is in most of the cases disrupted, maxillary and mandibular bone grafting can be performed at the same surgical time (68). Furthermore, these patients are often very young during management of this condition, ABG procedure is widely documented in the literature with a proven clinical track record of more than forty years (5), ZI is a

most recent surgery which is maybe not at the moment an intervention adapted for the youngest patients given that shorter clinical experience.

In our oral and maxillofacial surgery department, when we started to perform ZI surgery, this solution was proposed in older patients as a “rescue solution” after failure or in case of refusal of bone grafting conventional techniques. Besides, our patients in ZI group were statistically older than patients in ABG group. Some patients refused ZI with FP-3 restauration, demanding a less cumbersome restauration and thus an ABG even though our study shows that OHRQoL is the same whether choosing ZI procedure or ABG followed by CI placement. Currently, ZI is easily proposed as a first-line management.

5. Conclusion

ZI already showed a major interest in prosthetic rehabilitation of patients with maxillary defects after surgical treatment of benign or malignant tumors, traumas or within the context of congenital malformations. Even if this technique is still relatively little known to general dentists, ZI must now be considered as a full-fledged therapeutic solution, fully adapted to edentulous patients with maxillary atrophy.

ZI are a valid alternative to bone grafts for the fixed rehabilitation of atrophic edentulous maxillae and can be proposed as a first-line management. The type of surgery does not seem to affect the final OHRQoL, the type of prosthesis either.

However, this solution reveals its limitations in cases of major class III skeletal discrepancy, large oroantral fistula or in youngest patients with anodontia for which LFIO associated with ABG appears to be more suitable.

One solution is no better than the other, ZI holds many advantages like a reduced morbidity and treatment duration or immediate loading, even if LFIO associated with ABG maintains its indications.

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Thèse d'exercice / Chir. Dent. / Lille / 2020 – N° :

La réhabilitation du maxillaire atrophique : autogreffe osseuse et implants conventionnels *vs* implants zygomatiques / **Alexandre LAVENTURE** / 48 p. ; 17 ill. ; 68 réf.

Domaines : chirurgie orale ; implantologie.

Mots-clés RAMEAU : Implantologie dentaire ; Maxillaire supérieur ; Os – Greffe ; Ostéotomie ; Prothèses dentaires complètes ; Patients – Satisfaction.

Mots-clés FMeSH : Maxillaire ; Os zygomatique ; Transplantation osseuse ; Ostéotomie maxillaire ; Mise en charge immédiate d'implant dentaire ; Qualité de vie.

Introduction : La greffe osseuse autogène (GOA) – associée ou non à une ostéotomie de Le Fort I (OLFI) – et les implants zygomatiques (IZ) sont deux techniques fiables pour la réhabilitation fixe des maxillaires atrophiques édentés. Les IZ permettent de réduire la durée de traitement grâce à l'absence de recours à une greffe osseuse et la possibilité de réaliser une mise en charge immédiate, avec en principe une réduction de la morbidité. L'objectif de cette étude était de comparer ces deux protocoles sur la qualité de vie liée à la santé orale (QVLSO). Nous avions aussi discuté de la morbidité postopératoire et de la satisfaction du patient, de la survie implantaire et prothétique, et des complications biologiques.
Matériels et méthodes : Tous les patients qui avaient bénéficié d'IZ ou d'une GOA suivie de la pose d'implants conventionnels (IC) pour une réhabilitation maxillaire fixe, de novembre 2011 à avril 2019, avaient été inclus. La QVLSO avait été évaluée par le questionnaire OHIP-14, la morbidité postopératoire et la satisfaction du patient par un questionnaire conçu par nous-mêmes.
Résultats : 21 patients avaient été inclus dans le groupe GOA, 22 dans le groupe IZ. Les scores OHIP-14 médians étaient respectivement de 6,5 (intervalle interquartile [IIQ] : 2,0–13,0) et 6,0 (IIQ : 3,0–10,0) sans différence significative (p = 0,97). Les scores de morbidité postopératoire et de satisfaction du patient étaient de 4,5 (IIQ : 2,0–9,0) et 9,0 (IIQ : 7,0–11,0) avec une différence significative (p = 0,003). Les taux de survie implantaire/prothétique étaient de 97,9 %/100 % et 97,1 %/95,5 %. Les taux de complications biologiques étaient de 33,3 % et 36,4 % sans différence significative (p = 0.83).
Discussion : Les IZ constituent une alternative valable aux greffes osseuses et peuvent être proposés comme un traitement de première intention dans la plupart des cas excepté pour les patients présentant une classe III squelettique majeure, une communication buccosinusienne étendue ou chez le patient jeune présentant une anodontie chez qui une OLFI associée à une GOA semble davantage adaptée.

JURY

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