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THÈSE

pour le

DIPLÔME D'ÉTAT DE DOCTEUR EN MÉDECINE

D.E.S de Chirurgie Générale

Par

Thanh Thuy NHAM

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**LES DEFIS DE LA REHABILITATION PROTHETIQUE EN RECONSTRUCTION
MAXILLO-MANDIBULAIRE PAR LAMBEAU LIBRE DE FIBULA**

REVUE SYSTEMATIQUE DE LA LITTERATURE

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Monsieur le Docteur Alain HOORNAERT

Monsieur le Docteur Benoit PIOT

Monsieur le Docteur Hélios BERTIN

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ABBREVIATIONS

CAD / CAM	Computer-aided design / Computer-aided manufacturing
CMA	Comprehensive Meta-Analysis (software)
FFF	Fibula Free Flap
MINORS	Methodological Index for Non-randomised Studies
OMC	Oro-maxillo-facial
ORN	Osteoradionecrosis
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines
DPR	Dental Prosthetic Rehabilitation
nr	No reported
RT	Radiotherapy
VSP	Virtual Surgical Planning

KEY POINTS

Question

How commonly are dental prosthetic rehabilitation current issues in patients with reconstructed jaws by fibula free flap?

Findings

In this review of 36 studies involving 1166 patients who underwent surgical reconstruction of the jaws with FFF, dental prosthetic rehabilitation (DPR) was reported in 53% of cases. Cancer was the main reason for bone resection. DPR with dental implant allowed better patients' satisfaction than conventional prosthesis. Immediate implantation in the fibula free flap permitted to reduce DPR delay with implant high survival rate even in case of post-operative radiotherapy. Virtual surgical planning improve the accuracy of DPR process.

Meaning

To improve quality of dental prosthetic rehabilitation and thus patients' satisfaction, implant supported prosthesis with immediate implantation in the grafted fibula helped by virtual surgical planification should be considered in first intention. These data must be clarified by further comparative studies with larger sample sizes.

ABSTRACT

Importance: Dental Prosthetic rehabilitation (DPR) is the ultimate key step in patients with reconstructed jaws by fibula free flap. However, a functional and satisfactory dental prosthesis in the shortest delay possible, is still a challenge in those patients.

Objective: To provide an overview of the surgical and the clinical outcomes of dental prosthetic rehabilitation in patients with reconstructed jaws with fibula free flap (FFF) and what are the current issues.

Evidence review: MEDLINE/PubMed, Embase, Scopus and Science Direct were searched from databases inception in October 2021 and were updated in March 2022 for studies describing dental rehabilitation for patients after a maxilla-mandibular reconstruction by fibula free flap. The primary outcome “dental prosthesis” was defined as the number of patients who complete DPR procedure with a dental prosthesis. Two reviewers independently screened studies for inclusion, extracted data and assessed the study quality.

Findings: 36 studies were included in the review, reported on a total of 1166 patients (range, 6-117 patients) who underwent reconstruction of the jaws by fibula free flap (FFF). Dental prosthetic rehabilitation prevalence was 53% and concerned mandible in 85.7% of cases. Prostheses supported by implants were used in 58.9%. It improves the quality of prosthetic rehabilitation and patients’ satisfaction compared to conventional removable prosthesis. Cancer was the most common aetiology of defects of the jaws with 58.3%. In all patients with reconstructed jaws by FFF, post-operative radiotherapy was described in 38.2% of cases. The current issues identified during the prosthetic rehabilitation process were post-operative radiotherapy, inadequate soft tissue environment, prosthetic corridor mismatch, fibula limited height. Patients’ satisfaction about their dental prosthesis remained underestimated by most of authors.

Conclusions and Relevance: Prostheses supported by implants improved patients’ quality of life compared to conventional prostheses and should be considered in first intention. Immediate dental implantation on the FFF grafted before radiotherapy showed high survival rate but success of implant-retained overdenture should be evaluated on studies with larger sample sizes. Performing virtual surgical planning improve DPR quality but the cost limit their use. Soft tissue management must be studied for their impact on quality of dental rehabilitation in further comparative studies.

Key words: Prosthetic, Dental rehabilitation, Fibula free flap, Reconstruction of the jaws

DENTAL PROSTHETIC REHABILITATION CURRENT ISSUES IN PATIENTS RECONSTRUCTED JAWS WITH FIBULA FREE FLAP: A SYSTEMATIC REVIEW

INTRODUCTION

Dental prosthetic rehabilitation (DPR) is the ultimate most important step after the reconstruction of the jaws by fibula free flap¹. It permits speech, chewing, swallowing, improving cheek and lip support and saliva retention. It restores an aesthetic smile and psycho-social life functions². What is more, in patients requiring postoperative radiotherapy (RT), extended dental extractions are needed in the irradiated area to prevent osteoradionecrosis (ORN) of the jaw. Thus, a large proportion of patients become edentulous³.

DPR can be performed with implant-supported prosthesis or removable conventional prosthesis⁴. Both improve patient's quality of life⁵. This last decade, implants are increasingly used due to an excellent survival rate, more than 90% in fibula osseous flap and demonstrated an excellent osteointegration⁶. Implants allow prosthesis stability, good retention with a significant upgrade function of masseter effort on the defect side⁷. Thus, irradiated implants show an excellent survival rate⁸ estimated at 90% when implantations occurred in the native jaws before radiation therapy. However, data concerning implants survival rates in the irradiated fibula free flap grafted remains less evaluated.

Several authors recognized the importance of prosthetic rehabilitation in patients' quality of life but there is no consensus about the ideal moment to begin the dental rehabilitation process. Given the lack of data-driven approaches to dental prosthetic rehabilitation after reconstruction of the jaw with FFF, the aim of this systematic review was to describe the outcomes and the current issues that could interfere with a successful dental rehabilitation.

MATERIALS AND METHODS

Data Sources and Search

This review adhered to the PRISMA Guidelines, including protocol registration with PROSPERO⁹ on October 21, 2021. The research was conducted in October 2021 and was updated in April 2022. The following databases were assessed: MEDLINE/PubMed, Scopus, Embase and ScienceDirect. The studies were selected from the recent literature published after January 2000. The search strategy was made by using the terms “free fibula flap”, “osseous flap”, “prosthesis rehabilitation”, “dental rehabilitation”, “dental implant”, “conventional prosthesis”, “prosthodontic rehabilitation” in combination with the Boolean operators AND OR (Table 1). Manual research was made in the reference lists, Google Scholar, and Research Gate to complement the electronic search. The Zotero software program (Corporation for Digital Scholarship) was used to manage the references and remove the duplicated studies¹⁰.

Table 1

Main search strategy

PICOS:

P= (free fibula flap) OR (osseous flap)

I= (prosthesis rehabilitation) OR (dental rehabilitation) OR (dental implant)
OR (conventional prosthesis) OR (prosthodontic rehabilitation)

C = -

O = (dental prosthesis)

S = -

Search (PubMed-Medline):

((free fibula flap) OR (osseous flap)) AND ((prosthesis rehabilitation) OR
(dental rehabilitation) OR (dental implant) OR (conventional prosthesis) OR
(prosthodontic rehabilitation))

Inclusion Criteria and Outcome Definition

Studies that described the treatment procedure and follow-up of dental prosthetic rehabilitation after jaws reconstruction with fibula free flap were included. Case reports, other literature reviews, articles with insufficient published data and studies that have confounded data with other osseous free flaps were excluded.

Data Extraction and Quality Assessment

It involved two reviewers oro-maxillo-facial (OMC) surgeons specialized in prosthodontic rehabilitation ((T.T.N.) and (C.K.)) independently, and if there was any disagreement, a third reviewer (J.L.) was consulted. First, the articles were screened for full-text reading based on a review of the titles and abstracts. Only the papers that were relevant based on reading of the full text were included in the analysis.

The first reviewer (TTN) extracted the relevant data from the eligible articles and organised them into tables, which were crosschecked by the second reviewer (CK). Quality of studies and the potential bias were assessed by the two reviewers using the Methodological Index for Non-randomised Studies (MINORS)¹¹ adapted for observational studies.

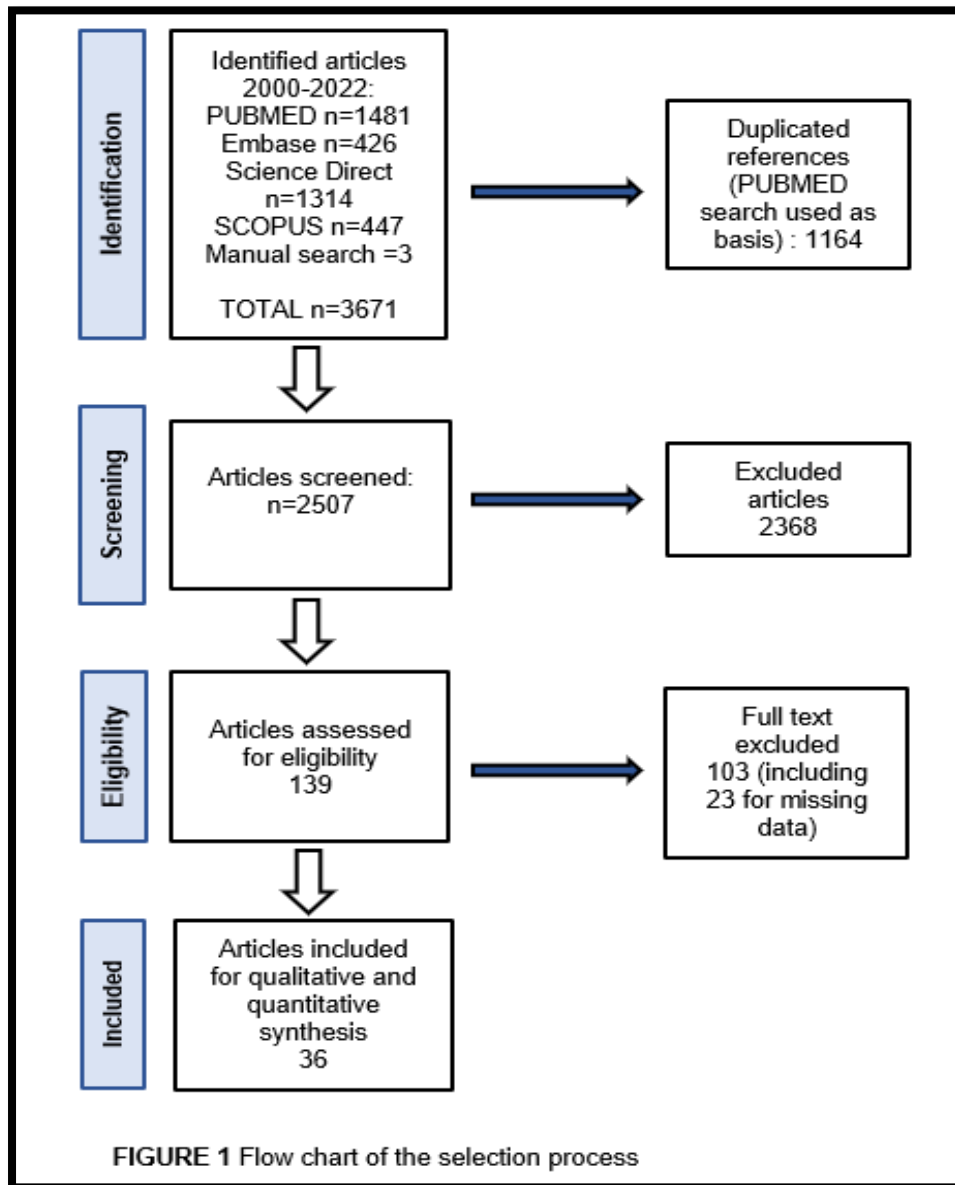
Data Synthesis

The extracted data consisted of information about the study design, patient's characteristics, post-operative radiotherapy, FFF harvested characteristics, the use of virtual surgical planning and dental rehabilitation outcomes. The statistical analysis was performed with Comprehensive Meta-Analysis Software for Windows (Comprehensive Meta-Analysis Software, Biostat Inc. Englewood, USA) to determine data prevalence with 95% confidence interval of different dichotomous outcomes.

RESULTS

Selection of the studies

After full-text review (Figure 1), 36 studies were included in the analysis. We selected the articles for which the data was the most detailed.



None was prospective, only three were comparative: the first compared immediate implantation versus delayed¹², the second rehabilitated versus non-rehabilitated patients after ameloblastoma resection¹³ and the last the use of Virtual Surgical Planning (VSP) versus no-VSP¹⁴. The number of patients studied was 6 for the smallest cohort¹⁵ to 117 for the biggest¹⁶. These studies evaluated 1166 patients

with 13,3 mean age for the youngest cohort¹⁵ and 68 mean age for the oldest¹⁷. The mean post-operative follow-up was ranged from 8¹⁷ to 121 months¹⁸. Reasons for bone resection were cancer with a prevalence of 58.3% (54.6-61.9%) $p < 0.001$ followed by benign tumours with 24% (20.5-27.8%) $p < 0.001$. Two studies^{19,20} hasn't reported the indications for bone resection. Data was resumed in Table 2. Overall rates for quantitative variables could not be calculated by CMA software, because of the lack of confidence intervals in most of studies.

Characteristics of the surgical reconstruction

The main reconstruction site concerned the mandible with 85.7% (82.1-88.7%) $p < 0.001$ ^{13,15,16,20-32} prevalence. The fibula free flap (FFF) harvested has a mean height only detailed in 2 studies: Bulat and al.³³ and Peng and al.³⁴ study respectively 11.24 mm and 15.2mm. The FFF mean length was detailed in 12 studies^{13,14,16,18,27,29,31-36} ranged from 6.8cm¹⁸ to 13.66cm²⁹. Double-barrel technique was reported on 16 studies^{13,18,20,22,23,28-30,32,33,36-41} and represented 28% (22.2-34.6%) $p < 0.001$ of the FFF harvested.

Success of prosthetic rehabilitation

Dental prosthetic rehabilitation (DPR) was defined by the presence of conventional prostheses or functional implants which could retain overdenture. Studies are separated into two subgroups. On the one hand, those which described DPR in patients reconstructed jaws with FFF: rates of DPR could be evaluated on 22 studies^{12,13,16,17,19,20,22,24-27,29,31,32,34,35,37,39,42-45}, reported from 21% to 94% and the prevalence was calculated at 53% (49.2-56.8%) $p = 0,119$. On the other hand, those which 100% of selected rehabilitated patients in the reconstructed with FFF to describe the outcomes^{15,18,21,23,28,30,33,36,38,40,41,46-48} of DPR.

The authors distinguished prostheses supported by implants and removable conventional prosthesis. Two studies used removable conventional prostheses exclusively^{15,35} 25 studies used implant supported prostheses only^{12-14,17,21-27,29,32,33,36-43,45-47} and 8 used both^{16-19,29,31,34,44}. Shroff and al, hasn't report type of PR²⁰. Prostheses supported by implant were performed in 58.9% (51.2-66.2%) $p = 0.024$. Implants were not functional for the final prostheses from 4%³⁸ to 37.8%²⁶ of the cases.

Patients' satisfaction was not quantified except on Bodard and all. study. They reported 96% of functional implant placed in the FFF grafted³⁸, 69.6% of 23 patients rehabilitated with dental implants have considered their occlusion as "satisfactory" and 74% has described their oral rehabilitation as "satisfactory".

Timing of prosthetic rehabilitation

Mean delay between the surgical reconstruction by FFF and the prosthetic procedure was described in 22 studies^{12,14,19,21-25,27,28,30,33,35-40,42,43,45,47}.

In 3 studies^{12,30,47}, prosthetic rehabilitation have begun during the reconstruction surgery with immediate implant placement in the FFF. In these studies, Shen Yu-Fu and al, have loaded prosthesis between 6-12 months while Allen and al. have performed between 4-6 weeks after immediate implantation on the fibula grafted. Williams and al. have not precise this detail.

Prosthetic rehabilitation has begun between 3 and 12 months post operative in 8 studies^{14,19,27,28,33,35,37,45} and after 12 months in 12 studies^{14,21-25,36,38-40,42,43}. The longest mean delay described was 28 months after surgical reconstruction with FFF²³.

Virtual surgical planning and Computer-aided design and manufacturing (CAD/CAM) modelling

Virtual surgical planning (VSP) involves collecting data prior to surgery as a foundation for diagnosis and the creation of a treatment plan that can be precisely reproduced in the operating room. Computer-aided design and manufacturing (CAD/CAM) technology for VSP was used by the authors for precision complex reconstructive surgery with FFF in 7 studies^{14,17,18,29,37,39,47}. Navarro-Cu  llar and al, is the only study that compared the used of CAD/CAM in twelve patients with reconstructed maxilla with FFF. Position of the bone in anatomical position was significantly better with 100% acceptable position versus 66% for no CAD/CAM group. Ischemia time was significantly shorter in the VSP group versus the no-VSP group, respectively 71min versus 96min $p=0.023$ like as operative time 6.7h versus 8.2h $p=0.027$ with better aesthetic results (83.3% vs 33,3% $p=0.036$). Procedural differences were found in the use of CAD/CAM technologies:

- Virtual Surgical planning without cutting guides or surgical template: Byun and al. has used CAD system with navigation for assistance in the surgery only because customized plates were not legal in Korea¹⁸. Shen Yi and al, had used only computer simulation and stereomodel to plan surgery without cutting guides²⁹.
- Cutting guides for osteotomies on the FFF and prefabricated plates to inset the fibula in the planned position^{12,14,17,37,39,47}.
- Surgical template for implantation guided, which allowed immediate or delayed placement of dental implant on the grafted fibula: Williams and al., have placed the fibula cutting guide with guided holes for implants placement secured with screws to the fibula when the flap remains on the leg to perfuse. Implants are placed prior to sectioning the bone.

Current issues in dental prosthetic rehabilitation

Twenty authors^{16–18,22,24–28,30,34–39,42–45} have described the current issues (Table 4). Exact quantification of each on the no-rehabilitated subgroup hadn't been carried out by the authors except 3 two teams^{24,34,45}. Pappalardo and al, were the only ones that compared rehabilitated (RH) versus no-rehabilitated (no-RH) in 34 patients affected by bone resection for ameloblastoma. They found that tumour location site, soft-tissue or bone defect characteristics did not affect significantly rate of prosthetic rehabilitation in these patients

Post-operative radiotherapy was the most issue reported by the authors^{17,18,25,27,28,35,37,38,43,45} with prevalence of 38.2% (33.8-42.8%) $p < 0.001$ in all patients with FFF reconstruction. These data were not mentioned by the authors in the rehabilitated or no-rehabilitated patients' subgroups. Dental implant survival in the fibula free flap grafted were evaluated without precision on success of DPR:

- 86% in Jacobsen's study⁴³, 93% in Hakim's study and 96% in Lodders' study²⁵ in case of immediate implantation on a non-irradiated fibula and without radiotherapy after the surgical reconstruction.
- 38% for Jacobsen's study, 55.3% for Lodders' study and 77% for Bodard's study in case of implantation in an irradiated FFF, with a mean delay after the irradiation of the FFF respectively to 12, 17 and 23.5 months.

- 89.6% in Hakim and al. study (mean follow-up 49.5 months) in case of implantation on the FFF placed before the radiotherapy adjuvant at 6 weeks after the ablative surgery. These dental implants are irradiated after their placement in the fibula grafted bone.

Inadequate soft tissue is the second current issue reported, it gathered: poor retention^{24,35}, thick skin flap in the FFF³⁶, hyperplastic reaction of peri-implant^{38,42}, large soft tissue defect^{22,45}. To avoid thick skin flap paddle, Fan and al. have proposed to use the fibula osteomyofascial flap with a remucosalized flap by surrounding mucosa within 1 month. They have found no significative differences in surgical complications or side effects after adjuvant radiotherapy. None of the patients required debulking in second procedure. In the osteomyofascial group 82% of patients were satisfied compared to 52% in the osseocutaneous flap. Only conventional prostheses were performed in this study. According to Chipasco and al., hyperplastic reaction tissue can be removing surgically or with topical applications of silver nitrate and substituted with palatal mucosa grafts.

Then, unfavourable relationship between maxilla and mandible^{25,26,38,44,45}, FFF failure^{17,24,25,27,39}, cancer recurrence^{24,25,27,39,45} were identified each 5 times as current issues followed by FFF limited height^{28,30,36,43} financial reason^{16,35,37,44} and death^{24,27,43,45}.

Other issues were less identified: poor oral condition (trismus^{24,27} or microstomia⁴⁵), paediatric population^{24,37}, low functional deficit^{24,44}, patient refusal or expectant attitude^{24,34}, poor cooperation^{17,27}, geographical distance to the hospital⁴³ and poor general physical condition²⁴.

Table 2 Study design and demographics data in all patients

Source	Study type	Sample size	Mean age	Mean Follow-up (months)	Mean delay*
Allen ¹² , 2020 (USA)	Retrospective comparative	27	63	12	0
Avraham ³⁷ , 2014 (USA)	Retrospective descriptive	52	44	33	3
Bodard ³⁸ , 2011 (France)	Retrospective	23	46	27,5	23,5
Bulat ³³ , 2021 (Russia)	Retrospective	8	50	14	3,5
Byun ¹⁸ , 2020 (South Korea)	Retrospective	9	49	121	nr
Chaine ³² , 2009 (France)	Retrospective	9	35	53	nr
Chiapasco ⁴² , 2006 (Italy)	Retrospective	59	59	55	12
Fan ³⁵ , 2016 (China)	Retrospective	51	51	nr	3
Fang ³⁶ , 2014 (China)	Retrospective	74	47	nr	13,5
Ferrari ²³ , 2013 (Italy)	Retrospective	14	50	110	28
Futran ¹⁹ , 2002 (USA)	Retrospective	27	59	26	5
Goker ³⁹ , 2020 (Italy)	Retrospective	14	52	54	24
Hakim ²² , 2015 (Germany)	Retrospective	37	52	95	12
He ²⁸ , 2011 (China)	Retrospective	7	40	28	8
Hundepool ²⁴ , 2008 (The Netherlands)	Retrospective	70	53	39,5	17,5
Iizuka ³¹ , 2005 (Switzerland)	Retrospective	28	58	48	nr
Jacobsen ⁴³ , 2014 (Germany)	Retrospective	34	38	23	17
Li ¹⁵ , 2009 (China)	Retrospective	6	13,3	24	nr
Lim ⁴⁴ , 2014 (Singapore)	Retrospective	44	29	nr	nr
Lodders ²⁵ , 2021 (The Netherlands)	Retrospective	44	60	59	23,5
López-Arcas ¹⁶ , 2010 (Spain)	Retrospective	117	57	46	nr
Navarro Cuéllar ¹⁴ , 2021 (Spain)	Retrospective comparative	12	58	11	6 (no-RT)-12(RT)
Ooi ³¹ , 2014 (Singapore)	Retrospective	30	27	59	nr
Pappalardo ¹³ , 2018 (Taiwan)	Retrospective	34	33,2	89	nr
Parbo ²⁷ , 2013 (Denemark)	Retrospective	36	54	22	9
Pellegrino ⁴⁰ , 2018 (Italy)	Retrospective	21	49,6	90	20,8
Peng ³⁴ , 2005 (China)	Retrospective	33	52	67	nr
Raoul ²¹ , 2009 (France)	Retrospective	31	46	76	16
Seier ¹⁷ , 2019 (Switzerland)	Retrospective	21	68	8	nr
Shen, Yi ²⁹ (China)	Retrospective	45	36	35	nr
Shen, Yu-Fu ³⁰ , 2015 (Taiwan)	Retrospective	10	31,6	83,7	0
Shroff ²⁰ , 2017 (India)	Retrospective	30	39,5	nr	nr

Smolka ⁴⁵ , 2008 (Switzerland)	Retrospective	56	56	44	6
Sozzi ⁴¹ , 2017 (Italy)	Retrospective	22	48	93,6	nr
Williams ⁴⁷ , 2021 (USA)	Retrospective	22	nr	nr	0
Zavattero ⁴⁶ , 2021 (Italy)	Retrospective	10	56	>24	nr

Table 2 (continued)

**Between surgical and the beginning of prosthetic procedure nr: non-reported data, RT: radiotherapy, RH: Dental prosthetic rehabilitated patient, VSP: Virtual Surgical Planning*

Table 3 Dental Prosthetic rehabilitation data

Source	DPR rate	Indication for bone resection		DPR type	Reconstruction site	VSP	FFF Mean Height (mm)	FFF Mean Length (cm)	FFF Double-barrel	Post-operative RT
		Cancer	Benign							
Allen ⁵⁰	78% (21/27)	89%	-	100 % DI	M (100%)	nr	nr	nr	56% (15/27)	
Avraham ⁴⁸	35% (18/52)	44%	27%	100 % DI	M (100%)	100%	nr	59%	31% (16/52)	
Bodard ⁴⁹	100% (23/23)	70%	-	100 % DI	M (100%)	nr	nr	4%	21,7% (5/23)	
Bulat ⁴⁵	100% (8/8)	-	-	100 % DI	M (100%)	100%	11,24	10,91	0%	0%
Byun ²³	100% (9/9)	89%	-	33% C & 67% DI	mx (100%)	11%	nr	6,8	0%	0%
Chaine ³⁷	22% (2/9)	-	100%	100 % DI	M (100%)	nr	nr	12	0%	0%
Chiapasco ³⁸	27% (16/59)	76%	12%	100 % DI	M(78%) & mx (22%)	nr	nr	nr	nr	nr
Fan ⁴⁶	61% (31/51)	78%	12%	100 % C	M (100%)	nr	nr	8	nr	59% (30/51)
Fang ⁴⁷	100% (74/74)	64%	5%	100 % DI	M (100%)	nr	nr	11,6	0%	nr
Ferrari ²⁸	100% (14/14)	36%	7%	100 % DI	M (100%)	nr	nr	nr	7%	nr
Futran ²⁴	52% (22/27)	nr	-	36% C & 64% DI	mx (100%)	nr	nr	nr	nr	nr
Goker ³⁹	79% (11/14)	57%	36%	100 % DI	M (93%) & mx (7%)	43%	nr	nr	29%	14% (2/14)
Hakim ²⁷	78% (29/37)	-	100%	100 % DI	M (92%) & mx (8%)	nr	nr	nr	8%	43% (16/37)
He ³³	100% (7/7)	43%	57%	43% C & 57% DI	M (100%)	nr	nr	nr	100%	43%
Hundepool ²⁹	26% (18/70)	70%	7%	100 % DI	M (100%)	nr	nr	nr	nr	nr
Iizuka ³¹	21% (6/28)	100%	-	100 % DI	M (100%)	nr	nr	nr	nr	68% (19/28)
Jacobsen ⁵¹	68% (23/34)	35%	3%	100 % DI	M (100%)	nr	nr	nr	nr	9% (3/33)
Li ²⁰	100% (6/6)	-	100%	100 % C	M (100%)	nr	nr	nr	nr	0%
Lim ⁵²	48% (21/44)	-	100%	86% C & 14% DI	M (100%)	nr	nr	nr	nr	0%
Lodders ³⁰	66% (29/44)	100%	-	100 % DI	M(86%) & mx (14%)	nr	nr	nr	nr	nr
López-Arcas ²¹	83% (97/117)	61%	13%	91% C & 9%DI	M (100%)	nr	nr	11,7	nr	nr
Navarro Cuéllar ¹⁹	100% (12/12)	100%	-	100 % DI	mx (100%)	50%	nr	8,8	nr	67%
Ooi ³⁶	60% (18/30)	-	100%	83% C & 17% DI	M (100%)	nr	nr	8,2	nr	0% (0/30)
Pappalardo ¹⁸	65% (22/34)	-	100%	100 % DI	M (100%)	nr	nr	8,1	40%	0%
Parbo ³²	94% (34/36)	78%	6%	100 % DI	M (100%)	nr	nr	7,1	nr	44% (16/36)

Pellegrino ⁴⁰	100% (21/21)	71%	29%	100 % DI	M(76%) & mx (24%)	nr	nr		10%	33%
Peng ⁴³	70% (23/33)	59%	32%	83% C & 17% DI	mx (100%)	nr	15,2	10,1	nr	nr
Raoul ²⁶	100% (31/31)	52%	13%	100 % DI	M(81%) & mx (19%)	nr	nr		nr	19%
Seier ²²	38% (8/21)	57%	5%	100 % DI	M(88%) & mx (14%)	100%	nr		nr	29% (6/21)
Shen, Yi ³⁴	27% (12/45)	11%	67%	8% C & 92% DI	M (100%)	100%	nr	13,66	100%	nr
Shen, YuFu ³⁵	100% (10/10)	-	100%	100 % DI	M (100%)	nr	nr		0%	0%
Shroff ²⁵	10% (3/10)	nr	nr	nr	M (93%) & mx(7%)	nr	nr		60%	nr
Smolka ⁵³	43% (24/56)	100%	-	100 % DI	M (100%)	nr	nr		nr	54% (30/56)
Sozzi ⁴¹	100% (22/22)	50%	32%	100 % DI	M(64%) & mx (36%)	nr	nr		9%	5%
Williams ⁴⁴	100% (22/22)	27%	50%	100 % DI	M (91%) & mx (9%)	100%	nr		nr	27%
Zavattero ⁴²	100/ (10/10)	50%	40%	100 % DI	M(70%) & mx (30%)	nr	nr		nr	20%

Table 3 (continued)

DPR: Dental Prosthetic Rehabilitation; FFF: Fibula Free Flap; DI: dental implants supported prostheses; C: Conventional prostheses; M: mandible site, mx: maxilla site; nr: non-reported dat; RT: radiotherapy

Table 4 Current issues reported

Current issues	Sources (DPR rate)
Post operative radiotherapy (x10)	Avraham ³⁷ [35%(18/52)]; Bodard ³⁸ [100% (23/23)]; Byun ¹⁸ [100% (9/9)]; Fan ³⁵ [61% (31/51)]; He ²⁸ [100% (7/7)]; Jacobsen ⁴³ [68% (23/34)]; Lodders ²⁵ [66% (29/44)]; Parbo ²⁷ [94% (34/36)]; Seier ¹⁷ [38% (8/21)]; Smolka ⁴⁵ [43% (24/56)]
Inadequate soft tissue (x7)	Bodard ³⁸ [100% (23/23): hyperplastic reaction]; Chiapasco ⁴² [27% (16/59): poor retention]; Fan ³⁵ [61% (31/51)]; Fang ³⁶ [100% (74/74): thick skin flap]; Hakim ²² [78% (29/37)]; Hundepool ²⁴ [26% (18/70): 4% of non RH-patients (3/70)]; Smolka ⁴⁵ [43% (24/56): large soft tissue defect]
Unfavourable relationship between maxilla and mandible (x5)	Bodard ³⁸ [100% (23/23)]; lizuka ²⁶ [21% (6/28): 45% of non-RH patients (10/22)]; Lim ⁴⁴ [48% (21/44)]; Lodders ²⁵ [66% (29/44)]; Smolka ⁴⁵ [43% (24/56)]
FFF Failure (x5)	Goker ³⁹ [79% (11/14)]; Hundepool ²⁴ [26% (18/70): 3% of non RH-patients (2/70)]; Lodders ²⁵ [66% (29/44)]; Parbo ²⁷ [94% (34/36)]; Seier ¹⁷ [38% (8/21)]
Cancer recurrence (x5)	Goker ³⁹ [79% (11/14)]; Hundepool ²⁴ [26% (18/70): 3% of non RH-patients (2/70)]; Lodders ²⁵ [66% (29/44)]; Parbo ²⁷ [94% (34/36)]; Smolka ⁴⁵ [43% (24/56)]
FFF limited height (x4)	Fang ³⁶ [100% (74/74)]; He ²⁸ [100% (7/7)]; Jacobsen ⁴³ [68% (23/34)]; Shen, Yu-Fu ³⁰ [100% (10/10)]
Death (x4)	Hundepool ²⁴ [26% (18/70): 37% of non RH-patients (26/70)]; Jacobsen ⁴³ [68% (23/34)]; Parbo ²⁷ [94% (34/36)]; Smolka ⁴⁵ [43% (24/56)]
Financial (x4)	Avraham ³⁷ [35%(18/52)]; Fan ³⁵ [61% (31/51)]; López-Arcas ¹⁶ [83% (97/117)]; Lim ⁴⁴ [48% (21/44)]
Poor oral condition(x3)	Hundepool ²⁴ [26% (18/70): trismus with 4% of non RH-patients (3/70)]; Parbo ²⁷ [94% (34/36): trismus]; Smolka ⁴⁵ [43% (24/56): Microstomia]
Paediatric population (x2)	Avraham ³⁷ [35%(18/52)]; Hundepool ²⁴ [26% (18/70): 1.4% of non RH-patients (1/70)]
Low functional deficit after FFF (x2)	Lim ⁴⁴ [48% (21/44)]; Hundepool ²⁴ [26% (18/70): 4% of non RH-patients (3/70)]
Patient refusal (x2)	Hundepool ²⁴ [26% (18/70): 5.7% of non RH-patients (4/70)]; Peng ³⁴ [70% (23/33): 40% of non-RH patients (4/10)]
Poor cooperation(x2)	Parbo ²⁷ [94% (34/36)]; Seier ¹⁷ [38% (8/21)]
Patient expectant attitude (x1)	Peng ³⁴ [70% (23/33): 60% of non-RH patients (6/10)]
Poor general physical condition (x1)	Hundepool ²⁴ [26% (18/70): 4% of non RH-patients (3/70)]
Geographical distance to the hospital (x1)	Jacobsen ⁴³ [68% (23/34)]

DPR: Dental Prosthetic Rehabilitation, Non-RH : non-Rehabilitated patients

DISCUSSION

In this systematic review, more than half of patients with reconstructed jaws by FFF were concerned by dental prosthetic rehabilitation and almost two-thirds of those patients had prostheses supported by implants.

Quality of prosthetic rehabilitation with implant supported prostheses

Oral rehabilitation using dental implants aim to restore both oral and aesthetic functions in the last three decades¹. Its advantages compared to conventional removable prostheses are: better retention, stabilization⁴⁹ and quality of life^{50–53} with an impact on speech and swallowing in addition to aesthetic outcomes⁵⁴. In this review, conventional prostheses easily shows high rates of rehabilitated patients^{4,15,16} but the authors didn't give any information about their real functionality. In case of DPR with implant retained-overdenture Bodard and al. and Shen Yu-Fu reported from 74% to 100% patients' satisfaction. It reflects the high quality of prosthetic rehabilitation with dental implants. Thereby, prostheses supported by implants in patients with reconstructed jaw with FFF should be considered in first intention.

Eligible patients for dental prosthetic rehabilitation with implants

Proposing prosthetic rehabilitation by dental implants involves defining eligibility criteria as argued Raoul and al., Ferrari and al. and Hundepool and al. studies^{21,23,24}: patient good cooperation, good oral hygiene and no periodontal disease, good residual tongue function, favourable prognosis, no alcohol and tobacco, no trismus, and no serious systemic comorbidities⁵⁵.

In our review, only one study concerned the paediatric population¹⁵ and none has been rehabilitated with dental implants without author's explanations. However, data from literature suggest that DPR with dental implant could be safely used on the grafted fibula in paediatric populations with reconstructed jaws. Genden and al, have described DPR with dental implant in FFF grafted in 2 children affected by aggressive fibroma without additional impact on the growth of their jaws. These patients demonstrated normal growth at the donor site, symmetry of the mandible and the maxilla with long-term follow-up⁵⁶. According to Bohner and al, the use of implants in

children could be proposed in the native jaws, in the anterior region of maxilla and mandible, after 10 years old to avoid structural and growth-related complications⁵⁷.

Favourable prognosis as eligible criteria does not mean eliminating patients which were affected by malignant tumours. Moreover, malignant tumours are the most common causes of defects of the jaws in our systematic review, representing 58.3% of the reconstructed patients. In our review, some studies had shown high prevalence (>60%) of prosthetic rehabilitation by dental implants^{12,25,27} in patients whose main aetiology of bone defect was cancer. Good survival in the stage IV oral squamous carcinoma patients concerned by fibula free flap reconstruction, reach now 81% at one year and more than 70% at three years⁵⁸ and could justify the proposing of dental rehabilitation as soon as possible. It remains for practitioners to consider post-operative radiotherapy.

Delay of dental implantation and post-operative radiotherapy

There is no consensus about the ideal moment to propose prosthetic rehabilitation by implants. The excellent primary stability of implants on FFF may allow immediate loading prostheses of the implants⁵⁹, especially in case of benign tumours resection or when radiotherapy is not considered. Success rate with primary implant placement is similar to those placed secondarily without an impact on flap survival⁶⁰. The beginning of the prosthetic rehabilitation procedure was immediate implantation, in all patients for Allen and al., Shen and al. and Williams and al. studies and for a quarter of the patients of Avraham and al study.

Immediate placement of implants in fibula grafted using or not Virtual Surgical Planning (VSP) may reduce the time required to achieve dental rehabilitation with a surgical complication rate similar to patients not concerned by VSP^{12,37}. Allen and all., has described a specific protocol: interdisciplinary planning session with VSP and CAD/CAM, an immediate dental implantation during the reconstruction surgery with FFF. It enables a complete DPR at 90 days postoperative without additional delay in the post-operative radiotherapy¹². These studies are the minority. Indeed, most of the

studies in this review reported delaying the procedure more than 12 months. The immediate approach in Allen's study would permit adequate time of osseointegration (6 weeks) before the damaging effects of radiation exposure, reduces the total number of procedures necessary to achieve dental restoration and shortens the overall time to final prosthesis placement¹². Immediate implantation on FFF grafted should be considered on further larger series of patients.

The best moment for dental implantation on patient concerned by irradiation treatment must be anticipated. Dental implant survival rates were similar in both native jaws and fibula grafts, and can exceed 96%^{8,25}. When implantation is prior to irradiation of the native jaws or fibula grafted bones, implant survival rates were also similar in both cases with 89%^{8,22}. In contrast, in case of implantation 12 months after the end of radiotherapy, in an irradiated fibula graft, implants survival rate drops to 38%⁴³. Implants failure didn't seem irreversible since 77% of implant survival rate was described if implantation on the fibula graft occurred meanly 23.5 months after the end of irradiation³⁸. Thereby, immediate implantation or before radiation therapy (at 6 weeks) in the grafted FFF would permit satisfaction survival rates. In case of delayed implantation on the FFF, implant survival would be better if implantation occurs two years after the irradiation of the FFF. These results should be interpreted with caution: implant survival rate does not necessarily reflect DPR success. Indeed, Koudougou and al. has reported that success of implant-retained overdenture⁸ was 67.4% for patient who underwent implant surgery before the RT on native jaws while implant survival rate was 89.6%. Further comparative studies must be conducted to evaluate DPR success rather than implant survival on reconstructed jaws with fibula grafts, with or without post-operative radiotherapy.

Virtual surgical planning and CAD/CAM modelling impact quality and delay of prosthetic rehabilitation

The unfavourable relationship between maxilla and mandible is one of the main current issue reported in this review and can lead to up to a third of unfunctional

implants²⁶. Unusable implants would compromise DPR success. Indeed, the main challenge in prosthetic rehabilitation is to position the FFF in a prosthetic corridor on the closest position to the native jaw and to get the subcrestal position of the implants. Virtual surgical planning (VSP) and CAD/CAM technologies have improved the quality of prosthetically guided outcomes of the reconstruction with FFF^{5,61}. It permits fabrication of cutting guides or templates implantation guides which could help accuracy and fidelity of VSP⁶²⁻⁶⁴ in dental implant functional positioning^{65,66}. It has an impact on operative efficiency with shorter ischemia time, decreased complication rates and allows to reduce the delay to get oral functional prostheses^{62-64,67-69}. In Navarro-Cuéllar study, FFF grafted presented better anatomical position and aesthetic results when VSP with CAD/CAM was used¹⁴. With a small sample size (12 patients), they have failed to demonstrate that VSP and CAD/CAM improve significantly DPR success rate.

In this review, the height difference between native jaws^{34,70} and FFF grafted bones^{33,34}, can reach 17mm especially in the symphyseal area. The consequence is an insufficiency of the vertical dimension of occlusion (VDO). From a functional viewpoint, the implants should support very long prosthetic suprastructures to reach the occlusal plane with the risk of unfavourable bending movements and implant overload, which may threaten long-term implant survival⁴⁷. The use of double-barrel technique fibula grafting was described to double the fibula bone height to 3cm. It is possible if the defect is less large than 10cm⁷¹. During the double-barrel fibula harvest^{65,66}, cutting or templates implantation guides made from the VSP and CAD/CAM modelling enhance the surgery accuracy^{65,66} but this technique could presents a risk of blocking the blood supply to the graft⁷¹⁻⁷⁴. Other techniques were described in literature, all relate to secondary surgeries: vertical distraction osteogenesis in the single barrel of FFF^{40,75} or osseous Iliac onlay grafted on the fibula²².

Virtual Surgical planning require additional time for creation of custom plates and models but none of patients affected by malignant tumours, experienced additional delay in ablative surgery⁴⁷. From an economic point of view, the cost of digital technologies being approximately 5000\$ can limit its use whereas the decreasing of operative room occupancy time can save money³⁷. Digital technologies allows workflow and planned surgery, but long-term and comparative studies with pharmacoeconomic considerations should be conducted to determine their efficiency on the quality of prosthetic rehabilitation.

The role of peri-implant soft tissue in the quality of dental rehabilitation

Peri-implant soft tissue is essential for long-term marginal bone stability around dental implants⁷⁶. The extraoral skin paddle of the FFF can be thick and has not alveolar attachment nor has it got a vestibule. Implants allow prosthesis stability, good retention and masticatory function. But thick skin paddle can lead to poor hygiene around dental implants. It results in peri-implantitis followed by marginal bone loss⁷⁶.

These patients need surgical reshaping³² in the majority of cases up to 62.2%²². Various techniques have been reported: the use of the fibula osteomyofascial flap with a remucosalized flap on the primary surgery³⁵ or split-thickness skin graft⁷⁷ and palatal mucosa graft after skin removal from the FFF skin paddle⁷⁸ on a second stage. Recent studies⁷⁹⁻⁸¹ have proposed the two-stage prefabricated vascularised fibula flap and a prelaminated with a skin graft to overcomes problems associated with bulky skin flaps. In this study, the limiting factors remains the time-delay, bone defects that doesn't include large soft tissue defects (tongue, buccal mucosa or soft palate), where local control is highly predictable and where radiotherapy adjuvant is not indicated⁷⁹. Further comparative studies should be conducted to determine results of systematic soft tissue management with vestibuloplasty or refine the skin paddle techniques.

Limitations

This meta-analysis focusses on retrospective observational studies which therefore does not consider confounding biases. These studies are limited by heterogeneous cohorts and aetiologies with sometimes small sample size. There is also, a lack of consensus on the definition of successful prosthetic rehabilitation which is not about having a prosthesis in the oral cavity. The definition of a successful DPR should be the one that takes patient's satisfaction into account. Although, quality of life is regularly cited as better in patients with DPR¹³, evaluation of patients' satisfaction remains underestimated.

There is undoubtedly publication bias. The nationalities of the studies are those of the industrialized countries. Prosthetic rehabilitation remains an expensive process and its accessibility is still limited to poor populations^{82,83}. The financial limitation is regularly highlighted in this review but paradoxically having a favourable health care system doesn't mean high DPR rates²⁶.

Further controlled and randomized studies, with assessment of the quality as success of dental prosthetic rehabilitation are required.

Conclusion

Prostheses supported by implant improve patient’s quality of life and satisfaction compared to conventional prostheses. It should be proposed in first intention in the patients’ reconstructed jaws with fibula free flap (FFF) whatever the bone defect aetiology. Immediate implantation on the grafted fibula, before radiotherapy improve dental implant survival rate but success of implant-retained overdenture should be evaluated in further comparative studies. Virtual surgical planning and CAD/CAM improve the quality of surgical reconstruction, prosthetic rehabilitation and thus patient satisfaction but their high cost limits their use. Further comparative studies should be conducted focusing on the surgical management of thick skin paddle and vestibuloplasty to determine their impact on the quality of rehabilitation.

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**LES DEFIS DE LA REHABILITATION PROTHETIQUE EN RECONSTRUCTION MAXILLO-
MANDIBULAIRE PAR LAMBEAU LIBRE DE FIBULA:
REVUE SYSTEMATIQUE DE LA LITTERATURE**

RESUME

Introduction: La réhabilitation prothétique dentaire est l'étape la plus importante pour finaliser la reconstruction maxillo-mandibulaire par lambeau libre de fibula. Toutefois, obtenir une prothèse fonctionnelle et satisfaisante pour le patient dans les plus courts délais, reste un défi actuel majeur. L'objectif est d'étudier les problématiques actuelles de la réhabilitation prothétique à travers les données chirurgicales et les résultats cliniques dans cette revue systématique de la littérature.

Matériel et méthodes: MEDLINE/PubMed, Embase, Scopus and Science Direct ont été consultées pour concevoir la base de données en octobre 2021 et mise à jour en mars 2022. Le critère de jugement principal " prothèse dentaire" était défini comme le nombre de patient ayant terminé la procédure de réhabilitation prothétique par une prothèse dentaire. Deux examinateurs indépendants ont inclus les études, extrait les données et évalué la qualité des études.

Résultats: 36 études ont été incluses, portant sur un nombre total de 1166 patients concernés par une reconstruction maxillo-mandibulaire par lambeau libre de fibula. La prévalence estimée de la réhabilitation prothétique dentaire était de 53% et concernait la mandibule dans la majorité des cas avec 85.7%. L'utilisation des prothèses stabilisés sur implants était majoritaire avec 58.9% des cas. En comparaison aux prothèses conventionnelles, ceux-ci amélioreraient la qualité de la réhabilitation prothétique ainsi que la satisfaction des patients. L'étiologie cancéreuse à l'origine du défaut osseux était la plus fréquemment retrouvée avec 58.3% des cas. Parmi tous les patients reconstruits des mâchoires par lambeau libre de fibula, 38.2% ont été irradiés en post-opératoire. L'implantation immédiate dans la fibula greffée avant la radiothérapie, montrait des taux de survie implantaire supérieur à 89%. Les problématiques les plus souvent reportées au cours du processus de reconstruction étaient : l'impact de la radiothérapie post-opératoire, la gestion des tissus mous et le couloir prothétique inadapté. La satisfaction et la qualité de vie des patients ont été sous-évalués par la majorité des auteurs.

Discussion: Les prothèses implantaires offrent une meilleure qualité de vie aux patients en comparaison aux prothèses conventionnelles et doivent être envisagées en première intention quelle que soit l'étiologie de défaut osseux. L'implantation immédiate dans la fibula greffée avant radiothérapie doit être évaluée selon le succès prothétique sur de plus grands effectifs de patients. La planification virtuelle avec chirurgie guidée améliore la qualité de la reconstruction mais le coût élevé limite son utilisation. Les techniques de plastie de la palette cutanée fibulaire doivent être étudiées dans des études comparatives sur le long terme pour déterminer leur impact sur la qualité de la réhabilitation.

Mots clés : réhabilitation prothétique ; réhabilitation dentaire ; lambeau libre de fibula ; reconstruction maxillo-faciale, reconstruction mandibulaire, reconstruction maxillaire.