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Functional jaw muscle assessment in patients with a full fixed prosthesis on a limited number of implants: A review of the literature

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Background: Full fixed prosthesis on a limited number of implants (FFP) are a viable treatment option for edentulous patients with a reduced amount of residual bone. Jaw muscular function in FFP patients has been evaluated in several studies, however heterogeneous data emerge from literature.
Purpose: The aim of this review of the literature was to assess the function of jaw muscles in edentulous patients restored with full fixed prostheses on a limited number (≤ 6) of implants, as compared to dentate subjects and edentulous subjects wearing dentures, implant-supported overdentures or full fixed prostheses supported by more than six implants.
Materials and methods: An electronic search of databases up to December 2013 was performed. The articles were selected using specific inclusion criteria, independent of the study design.
Results: A total of 1598 records were identified. After removing the duplicates and excluding records based on title and abstract, only 37 eligible records were identified. After full-text review, seventeen studies were selected for analysis according to the inclusion criteria. From the included studies, only one evaluated masseter muscle thickness in a cross sectional study by means of ultrasound, while the 16 remaining papers evaluated muscular function by using electromyography (EMG). Those studies analysed several heterogeneous parameters throughout the execution of five functional tests and were therefore described and pooled according to the following task categories: clenching; swallowing; reflex and fatigue for statics; and chewing for dynamics.
Conclusions: The results of selected studies seem to indicate that, compared to dentate controls, FFP patients display a global satisfactory neuromuscular equilibrium in static activities, but still have some impairment during chewing.

Conflict-of-interest statement: *The authors declare that they have no conflict of interest.*

■ Introduction

After tooth extraction, the alveolar process undergoes an extended resorption[1]. In completely edentulous subjects, the reduced bone height in posterior mandibular and maxillary areas confines implant placement to the median regions, thus limiting the prosthetic treatment options. As reported in several studies for edentulism, full fixed implant-supported restorations significantly increase patient satisfaction and masticatory function compared to implant-retained prostheses or dentures[2,3]. However, when severe jaw atrophy occurs, important bone augmentation/regenerative surgeries are needed to allow implant placement in posterior areas that support distal prosthesis extensions. Augmentation procedures are operator-dependent, invasive, expensive, and with a high risk of complication. Longer time intervals are also imposed to complete the rehabilitation[4].

The placement of distally tilted implants[5,6] or distal short implants was proposed to improve bone anchorage and prosthetic support on a limited number of implants in the frontal areas, thus avoiding regenerative surgeries. Studies report promising results at short and long-term evaluations for the All-on-four and All-on-six treatment approaches [7,8]. From a masticatory point of view, direct and indirect methods have been used to assess the function of jaw muscles in edentulous patients wearing prostheses on implants[9]. Direct methods use instruments (electromyography, ultrasounds) to measure muscular tasks in both static (clenching, interarch stability) and dynamic (chewing, neuromuscular coordination) situations[10,11]. Otherwise indirect methods deduce the efficiency of mastication by measuring the bite force, the effects of chewing on food crumbling/breaking down and mixing, and the mastication time, until all of the food bolus is swallowed[12,13]. However, these techniques have different and specific outcomes, thus heterogeneous data on masticatory function emerge from the literature.

The aim of the present review was to assess the function of jaw muscles in edentulous patients restored with full fixed prosthesis on a limited number (≤ 6) of implants (full fixed prosthesis or FFP), compared to dentate subjects and edentulous subjects wearing dentures, implant-supported overdentures or FFP on a higher number (>6) of implants.

Methods

Eligibility criteria

Types of studies

The inclusion criteria for studies were: clinical trials and randomised controlled clinical trials published in English (no publication date or publication status was imposed); no unpublished studies were included.

Types of participants

Patients of any age and gender treated for complete maxillary and/or mandibular edentulism were considered.

Types of interventions and criteria for inclusion/exclusion

Trials that assessed by using direct methods (electromyography or EMG, ultrasonography) jaw muscle function in edentulous patients restored with full fixed prosthesis on up to six implants, compared with patients restored with dentures, removable implant retained prostheses, or full fixed prostheses on more than six implants, or dentate patients, were included.

Studies evaluating jaw muscle function by indirect methods (i.e. food mixing, food crumbling/breaking down, mastication time until the entire food bolus is swallowed, bite force, pattern of movement), were excluded.

Studies evaluating patients treated with mandibulectomy for oncologic reasons, or patients that underwent bone augmentation/regenerative procedure prior to implant placement were also excluded.

Types of outcomes

The primary outcome was the assessment of neuromuscular function of jaw muscles in edentulous patients restored with full fixed prosthesis on up to six implants.

Search strategy

Studies were identified by the Medline (Pub Med) electronic databases and the last search was performed on 30 December, 2013.

Hand search by scanning reference lists of included articles and reviews, as well as consultation with experts in the field were performed. Authors were contacted in order to acquire missing information.

The search terms were: 'EMG'; 'Electromyography'; 'Temporal'; 'Fixed dental prosthesis'; 'All-on-four'; 'All-on-six'; 'Dental implant'; 'Oral implant'; 'Full fixed prosthesis'; 'Limited number of dental implants'; 'Masseter'; 'Reduced number of dental implants'; 'Jaw muscle assessment'; 'Masticatory muscle assessment'; 'Jaw muscle'; 'Masticatory muscle'; and 'Chewing'. They were used alone or in combination using Boolean operators OR and AND.

Study selection

Two independent reviewers (GP and RR) first excluded irrelevant records by their title and abstract. In order for them to be included in the review, the full texts of the remaining papers were evaluated by two independent reviewers (CD and GP); disagreements between reviewers were solved by consensus.

Data extraction and management

To perform a statistical comparison between articles, studies that used similar protocols were selected and the data of comparable outcome variables were extracted. The data extracted from studies reporting comparable outcomes were imported in the software RevMan (Review Manager [RevMan] Version 5.2, 2012, The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark) and submitted to meta-analysis. A random effect model was chosen. The estimates of the various parameters were expressed as mean difference together with 95% confidence intervals (CI). The statistical evaluation was conducted considering the patient as the analysis unit. The outcomes were presented as forest plots.

Results

Search

A total of 1598 records were identified from all databases and by hand search. After removing the duplicates and excluding records (based on title and abstract) because they were non-relevant, only 37 records were selected. Full-texts of the selected records were carefully read and 20 articles were excluded because they did not meet the inclusion criteria. Papers excluded at this second step and reasons for exclusion were reported in Table 1[12-31]. Fig 1 depicts the screening process. At the end, a total of 17 articles were included in this review (Table 2).

Table 1 Excluded studies and reasons for exclusion.

Study	Reason for exclusion
Akeel et al, 1993[14]	Masticatory efficiency evaluated by chewing Optosil tablets
Berretin-Felix et al, 2009[15]	Masticatory function evaluated with tactile sensitivity of the face and observation of food intake, masticatory type, formations of bolus and pain during mastication. Swallowing evaluated by observation of clinical signs related to the oral and pharyngeal stages of swallowing, as well as the presence of food residue
Book et al, 1992[16]	Masticatory function evaluated by registrations of mandibular movement characteristics and maximal bite force
Carlsson & Lindquist, 1994[17]	Evaluated maximal occlusal force or mastication efficiency index
Albuquerque et al, 2000[18]	Masticatory function evaluated by mastication tests and psychometric evaluations using visual analog scales and categorical scales
Dellavia et al, 2007[19]	Enrollment of hemimandibulectomy-reconstructed patients
Haraldson & Zarb, 1988[20]	Jaw muscle function evaluated by assessment of bite force
Jemt et al, 1985[21]	Chewing pattern evaluated by assessment of mandibular movement
Jemt & Lindqvist, 1985[22]	Chewing pattern evaluated by assessment of mandibular movement
Jemt, 1986[23]	Chewing pattern evaluated by assessment of mandibular movement
Jemt & Carlsson, 1986[24]	Masticatory function assessed by chewing efficiency index and bite force
Karlsson & Jemt, 1991[25]	Masticatory rhythmical pattern assessed by registration of masticatory cycle duration, mandibular velocity and displacement
Lindquist & Carlsson, 1985[26]	Masticatory function evaluated by means of a questionnaire, a comminution test for chewing efficiency and bite measurements
Lundqvist & Haraldson, 1990[27]	Evaluation of occlusal relationship, chewing force, chewing efficiency and interocclusal threshold
Lundqvist & Haraldson, 1992[28]	Evaluation of occlusal relationship, chewing force, chewing efficiency and interocclusal threshold
Luraschi et al, 2012[13]	Evaluation of active tactile sensitivity and bite force
Matsui et al, 1996[12]	Enrollment of patients with tumours of the oral cavity and mandibulectomy. Chewing performance evaluated by a low-adhesive, colour-developing, chewing-gum system
Mericske-Stern et al, 2000[29]	Measurements of bite force
Roumanas et al, 2006[30]	Masticatory and swallowing threshold performance assessed by test food
Yan et al, 2008[31]	Full-fixed prosthesis sustained by a large number of implants

Table 2 Characteristics of the included studies.

Study	Patients group (n)	Mean age in years (range)	Maxillary prosthetic rehabilitation	Mandibular prosthetic rehabilitation	Number of implants in FFP	Period of edentulism (months)	Follow-up (months)
Haraldson et al, 1979[37]	A) 13, B) 10	A) 56 (42–59), B) 55 (42–64)	A) FFP or PFP, B) Dentate	A) FFP or PFP, B) Dentate	3–8 (maxilla), 4–6 (mandible)	6–66	\
Haraldson & Ingervall, 1979[38]	A) 13, B) 10	A) 56 (42–59), B) 55 (42–64)	A) FFP or PFP, B) Dentate	A) FFP or PFP, B) Dentate	3–8 (maxilla), 4–6 (mandible)	6–66	30
Haraldson, 1983[39]	A) 13, B) 10	A) 56 (42–59), B) 55 (42-64)	A) FFP or PFP, B) Dentate	A) FFP or PFP, B) Dentate	3–8 (maxilla), 4–6 (mandible)	6–66	30
Bonte & van Steenberghe, 1991[43]	A) 5, B) 2, C), 6, D) 2, E) 2	\	A) FFP, B) FFP, C) FFP, D) Partially dentate, E) Dentate	A) FFP, B) PFP, C) Partially dentate, D) Partially dentate, E) Dentate	\	\	\
Feine et al, 1994[34]	A) 8, B) 8	30–62	A) Denture, B) Denture	A) FFP then Overdenture, B) Overdenture then FFP	4–5	120	2
Duncan et al, 1992[46]	A) 10, B) 10, C) 10	57.7	A) Denture, B) Denture, C) Dentate	A) Denture, B) FFP, C) Dentate	4–5	\	\
Jacobs & van Steenberghe, 1995[45]	A) 8, B) 2, C) 10, D) 10, E) 10	56 (24–72)	A) FFP, B) PFP, C) PFP, D) Denture, E) Dentate	A) FFP, B) FFP, C) Dentate, D) Overdenture, E) Dentate	4–6	\	\
Jacobs et al, 1995[32]	A) 10, B) 7	A) 56 (40–68), B) 50 (34–62)	A) Denture / Dentate, B) FFP/ Denture/Dentate	A) Overdenture, B) FFP/Denture/Dentate	4–7	A) 168 B) 156	up to 24
Jacobs & van Steenberghe, 1993[44]	A) 16, B) 20, C) 9, D) 8	A) 50 (33–67), B) 60 (46–82), C) 65 (52–64), D) 45 (26–64)	A) Denture, B) Denture, C) FFP/Denture, D) Dentate	A) Denture, B) Overdenture, C) FFP/Denture, D) Dentate	5–6	A) 180, B) 80, C) 48	12
Ferrario et al, 2004[36]	A) 7, B) 7, C) 5	A) 58 (45–75), B) 65 (45–79, C) 53 (45–57)	A) FFP, B) Denture, C) Dentate	A) FFP, B) Overdenture, C) Dentate	6 (maxilla), 6 (mandible)	\	A) 6, B) 3 to 6
Berretin-Felix et al, 2008[33]	15	66 (60–76)	Denture	Denture (FFP after surgery)	5	60	18
Tartaglia et al, 2008[10]	A) 5, B) 5, C) 7, D) 8	A) 61 (50–71), B) 60 (52–66), C) 64 (54–80), D) 51 (40–69)	A) FFP, B) Denture, C) FFP/Dentate or teeth-supported fixed prosthesis, D) Dentate	A) FFP, B) FFP, C) FFP/Dentate or teeth-supported fixed prosthesis, D) Dentate	6 (maxilla), 6 (mandible)	\	6
Bersani et al, 2011[41]	A) 28, B) 28	A) 46–85, B) 45–82	A) Denture, B) Dentate	A) FFP, B) Dentate	5	\	\
Grigoriadis et al, 2011[40]	A) 13, B) 13	A) 71 (58-82), B) 66 (59-79)	A) FFP, B) Dentate	A) FFP, B) Dentate	6 (maxilla), 4–5 (mandible)	\	12
Dellavia et al, 2012[35]	A) 10, B) 8, C) 8	A) 61 (50–74), B) 62 (53–73), C) 60 (56-69)	A) Denture, B) FFP, C) Dentate	A) FFP, B) FFP, C) Dentate	4 (maxilla), 4 (mandible)	\	12
Muller et al, 2012[11]	A) 20, B) 20, C) 20, D) 20	A) 68, B) 61, C) 68, D) 66	A) Denture, B) FFP C) Denture, D) Dentate	A) Overdenture, B) FFP, C) Denture, D) Dentate	6–8 for arch	84–108	12
De Rossi et al, 2013[42]	A) 21, B) 21, C) 21	58 (32–75)	A) FFP, B) Denture, C) Dentate	A) FFP, B) Denture, C) Dentate	4 (maxilla), 4 (mandible)	\	6

PFP = implant-supported partial fixed prosthesis wearers; FFP = implant-supported full fixed prosthesis wearers.

Between selected studies (17), only one evaluated muscle thickness in a cross sectional study, and was reported separately[11]. Müller et al[11] observed by means of ultrasound scanners the masseter muscle thickness of dentate subjects and edentulous patients restored with: (i) maxillary dentures and mandibular implant-supported overdentures (C/OD); (ii) upper and lower implant-supported fixed prosthesis (FFP/FFP); or (iii) conventional upper and lower complete dentures (C/C). The authors reported the thickest muscle in dentate patients and the thinnest in the C/C group (P <0.0001), and a lower but not significantly different value in FFP/FFP and C/OD groups than dentate.

All of the 16 remaining papers (Tables 3 to 7) evaluated muscular function by means of EMG and analysed several parameters throughout the execution of functional tests (i.e. clenching, maximum voluntary contraction). For this reason the articles were described and pooled in the following task categories: (i) fatigue; (ii) swallowing; (iii) muscle reflex; (iv) clenching; (v) chewing.

All studies were cross-sectional, except two that were longitudinal[32,33], and one within-subject crossover trial[34]. No randomised clinical trials were performed. Of the 17 included studies, 3 have been performed in Italy[10,35,36], 4 in Sweden[37-40], 3 in Brazil[33,41,42], 4 in Belgium[32,43-45], 1 in Canada[34], 1 in the US[46] and 1 in Switzerland[11]. All the studies were conducted at universities.

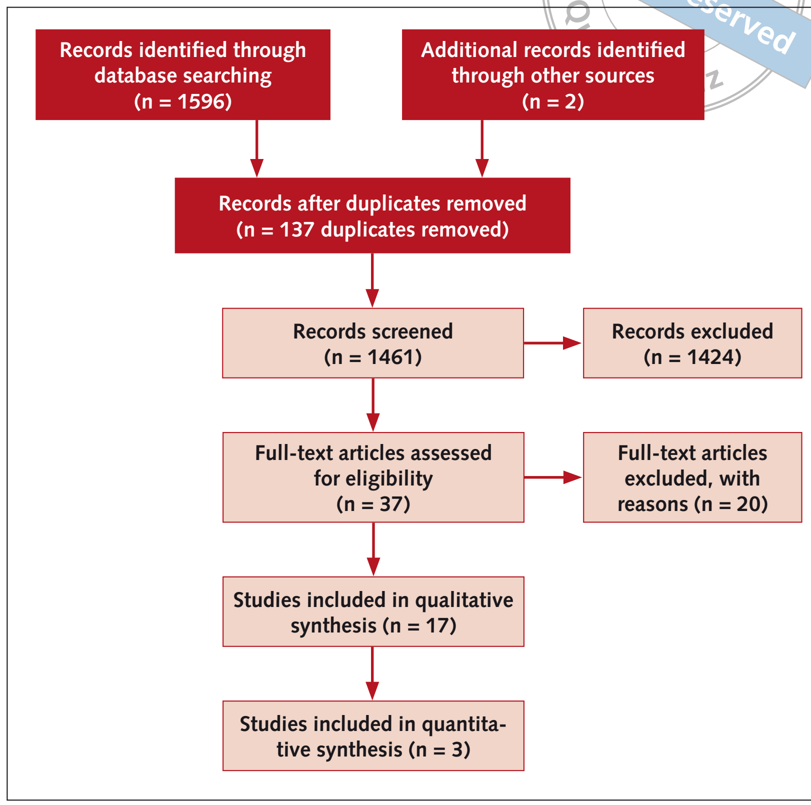

Fig 1 Flowchart of the study selection process.

Fatigue

The monitoring of muscle performance by assessing the fatigue task was done in two of the selected studies[32,44]. The resistance to fatigue and shifts in the power spectrum of the masseter muscle during a submaximal (50%) clenching effort was investigated. The authors observed that the EMG signal significantly

Table 3 Main outcomes of the included studies evaluating muscular fatigue.

Study	Group (n)	Measured parameter	Results
Jacobs et al, 1995[32]	A) Overdenture (10)	1) EMG amplitude range (µV) with and without fatigue	FFP increase EMG amplitude after 2 years
	B) FFP (7)	2) MPF (Hz) with and without fatigue	Only Overdenture wearers maintain a significant MPF downshift during sustained clench after rehabilitation
		3) Endurance time (s)	No differences in endurance time are measured
Jacobs & van Steenberghe, 1993[44]	A) Denture (16)	1) EMG amplitude range (µV) with and without fatigue	Dentate and Overdenture patients show a significant EMG amplitude decrease after fatigue effect
	B) Overdenture (20)	2) MPF (Hz) with and without fatigue	Only FFP patients do not show a significant reduction in MPF after fatigue
	C) FFP (9)	3) Endurance time (s)	No differences in endurance time are measured
	D) Dentate (8)		

FFP = implant-supported full fixed prosthesis wearers; MPF = EMG mean power frequency.

Table 4 Main outcomes of the included studies evaluating swallowing activity.

Study	Group (n)	Measured parameter	Results
Haraldson & Ingervall, 1979[38]	A) FFP (13) B) Dentate (10)	Amplitude EMG (μV) of AT, PT, M	No differences between groups
Berretin-Felix et al, 2008[33]	FFP (15)	Amplitude EMG (μV RMS) of M, submental muscle, superior orbicularis	With FFP significant reduction of EMG amplitude only for M at 6 and 18 months

FFP = implant-supported full fixed prosthesis wearers; AT = anterior temporalis muscle; PT = posterior temporalis muscle; M = masseter muscle; RMS = root mean square.

Table 5 Main outcomes of the included studies evaluating muscular reflexes.

Study	Group (n)	Measured parameter	Results
Bonte & van Steenberghe, 1991[43]	A) Dentate (2)	Post stimulus EMG complex (PSEC) after mechanical tooth stimulus (P, Q, R, S, T waves)	A) PSEC detected in both subjects (QR wave)
	B) FFP (5)		B) no PSEC
	C) FFP/PFP (2)		C) no PSEC
	D) FFP/partially edentulous (6)		D) PSEC in 5 patients (QR wave)
	E) Partially edentulous (2)		E) no PSEC
Duncan et al, 1992[46]	A) Dentate (10)	SPUR (silent period of the unloading reflexes) latency (ms)	The time of onset for the unloading reflexes was not significantly different among the three groups
	B) Denture (10)		
	C) Denture/FFP		
Jacobs & van Steenberghe, 1995[45]	A) FFP (8)	Post stimulus EMG complex (PSEC) after mechanical tooth stimulus	FFP have no reflexes in 7 of 8 patients. 1 patient has QR wave
	B) FFP with only one natural tooth in the maxilla (2)		Both FFP patients with natural teeth have a reflex response
	C) PFP (10)		7 of 10 patients with PFP have reflex responses
	D) Denture/PFP (10)		Only 5 patients with denture have reflexes with QR morphology
	E) Dentate (10)	Latencies Q-R-S-T wave (ms)	T wave only appears in the Dentate subjects

FFP = implant-supported full fixed prosthesis wearers; PFP = implant-supported partial fixed prosthesis wearers.

increased after fixing a prosthesis on implants and that it reached the levels of dentate control patients, thus indicating an improvement in masticatory muscle performance after FFP. Otherwise, patients restored with complete dentures or overdentures on implants had significantly lower EMG amplitudes than dentate controls. A significant downward indication of the mean power frequency was also observed for all patients (dentate, restored with dentures or overdentures), apart from those with FFP.

Swallowing

The amplitude of the muscle activity was recorded to assess muscular function during swallowing[33,38]. In a longitudinal interventional study[33], the authors observed a decrease of masseter muscular activity after the rehabilitation of patients wearing removable dentures in both jaws with implant-supported prostheses. A further cross-sectional study failed to find differences in EMG amplitude of masseter and anterior/posterior temporal muscles between dentate and patients with FFP[38].

Reflex

Studies evaluated the presence/absence and onset of a periodontal-masseteric reflex elicited by the application of a mechanical stimulus on a tooth. In particular, a standardised tap was delivered to an osseointegrated implant and the subsequent variations in the mean EMG activity during clenching were recorded as the 'post-stimulus complex' (PSEC), characterised by downward- and upward-

Table 6 Main outcomes of the included studies evaluating teeth clenching.

Study	Group (n)	Measured parameter	Results
Haraldson et al, 1979[37]		Mean EMG voltage (µV) during:	No group differences
	A) FFP (13)	1) postural position	
		2) maximal biting	
	B) Dentate (10)	3) biting with gentle force	
		4) biting with force equivalent to that used during mastication	
Jacobs & van Steenberghe, 1993[44]	A) Denture (16)	EMG amplitude range (µV) during clenching	Dentate subjects have greater EMG activity than denture and Overdenture wearers. Overdenture patients have greater EMG activity than denture wearers
	B) Overdenture (20)		
	C) FFP (9)		
	D) Dentate (8)		
Ferrario et al, 2004[36]	A) Denture (7)	Standardised EMG indexes (µV/µV%) during clenching	Dentate and FFP patients show greater AT symmetry during clenching. Maximal EMG activity result greater in Dentate than FFP and denture wearers
	B) FFP (7)		
	C) Dentate (5)		
Tartaglia et al, 2008[10]	A) FFP (5)	Standardised EMG indexes (µV/µV%) during clenching.	FFP show a significantly smaller AT to M ratio than other subjects. No other differences are measured
	B) Denture/FFP (5)		
	C) FFP/Dentate (7)		
	D) Dentate (8)		
Bersani et al, 2011[41]		EMG amplitude (µV) during:	
	A) Denture/FFP (28)	1) maximal voluntary clench	Great EMG values in R AT at rest in Dentate subjects
		2) protrusion	Smaller EMG values in R M in Dentate subjects
	B) Dentate (28)	3) left and right laterality	Great L AT activity in FFP during R and L laterality; smaller R and L M in Dentate subjects during right laterality
		4) rest	Smaller R M and L AT in Dentate subjects at rest
Dellavia et al, 2012[35]	A) Denture/FFP (10)	Standardised EMG indexes (µV/µV%) during maximal clenching.	Rehabilitated subjects show a significantly greater lateral displacement effect (torque coefficient). No other differences during maximal clenching are measured
	B) FFP (8)		
	C) Dentate (8)		
De Rossi et al, 2013[42]	A) FFP (21)	Standardised EMG indexes (µV/µV%) during maximal clenching and rest position.	During clenching, denture wearers show a lower R M activity than Dentate and FFP. At rest, denture wearers showed greater AT activity than other subjects. The L AT resulted in being more active in FFP than Dentate
	B) Denture (21)		
	C) Dentate (21)		

R = right, L = left; FFP = implant-supported full fixed prosthesis wearers; AT = anterior temporalis muscle; M = masseter muscle.

going waves. Latencies, peak latencies and surfaces of those waves can be quantified on the basis of a confidence interval computed from the full-wave rectified and averaged EMG physiologic fluctuations recorded during the pre-stimulus period[43,45].

In edentulous subjects with FFP in both jaws, the absence of a reflex response after application of a mechanical stimulus was observed[43,45]. However, when patients were partially edentulous or when the FFP was occluding with a denture, a reflex could be observed in some patients without differences in the onset of the jaw-unloading reflex[43,45,46].

Clenching

This task was analysed in seven of the selected reports[10,35-37,41,42,44]. No homogenous data arose from these studies evaluating EMG activity on patients restored with FFP, compared to dentate or patients wearing dentures. In two studies, muscular activity was significantly higher in dentate

Table 7 Main outcomes of the included studies evaluating a chewing task

Study	Group (n)	Measured parameter	Results
Haraldson & Ingervall, 1979[38]	A) FFP (13)	1) Chewing duration (s)	Duration significantly longer in FFP than in Dentate subjects for all muscles
		2) Chewing cycles (n)	No differences in chewing rate between FFP and Dentate patients and between different foods
	B) Dentate (10)	3) Maximal mean amplitude (μV) and duration of the closing phase of each cycle (ms)	No differences in amplitude, but longer duration in FFP than in Dentate subjects
		4) Onset of activity – peak per muscle in the closing phase	Onset of activity in M earlier in FFP than in Dentate subjects
Haraldson, 1983[39]	A) FFP (13)	1) Maximal mean amplitude (μV) in the closing phase of first 3 and last 3 cycles	No differences between FFP and Dentate patients
	B) Dentate (10)	2) Duration of the closing phase of first 3 and last 3 cycles (ms)	No differences in chewing rate between FFP and Dentate subjects and between different foods
		3) Onset of activity – peak per muscle in the closing phase	Onset of activity in M earlier in FFP than in Dentate subjects in the first 3 cycles chewing peanuts
Feine et al, 1994[34]	A) FFP (8)	1) Chewing duration (s)	Duration shorter in patients with Overdenture
	B) Overdenture (8)	2) Maximal mean amplitude (μV)	Tendency to less activity in Overdenture patients (significant only R M for bread)
Ferrario et al, 2004[36]	A) FFP (7)	1) Frequency (Hz) per side	No differences between groups
	B) Overdenture (7)	2) Confidence ellipse (%) per side	Tendency (but not significant) to smaller areas in Dentate than in FFP and Overdenture subjects
	C) Dentate (5)	3) Symmetry Masticatory Index (SMI)	Larger in FFP and Overdenture than in Dentate subjects
Berretin-Felix et al, 2008[33]	FFP (15)	1) Median amplitude (μV)	No significant differences pre- and post-surgery at any follow-up time
Tartaglia et al, 2008[10]	A) FFP (5)	1) Frequency (Hz) per side	No differences between groups
	B) FFP/Denture (5)	2) Total activity (μV) per side	Higher activity in FFP and FFP/Denture than in the other groups in both sides
	C) FFP/Dentate (7)	3) Total standardised activity (μvV/μV%) per side	Higher activity in FFP and FFP/Denture than in the other groups in both sides
	D) Dentate (8)	4) Confidence ellipse (%) per side	Larger areas in implant patients than in Dentate (difference significant only on the left side)
		5) SMI	No significant differences between groups
Grigoriadis et al, 2011[40]	A) FFP (13)	1) Normalised amplitude	Weaker increase with hard food and less reduction of signals over time in FFP than in Dentate subjects
	B) Dentate (13)	2) Chewing duration (s)	No differences between FFP and Dentate, but always increase with hard foods
		3) Chewing cycles (n)	No differences between FFP and Dentate, but always increase with hard foods
De Rossi et al, 2013[42]	A) FFP (21)	Maximal mean amplitude (μV) during chewing, in habitual and non habitual chewing	During chewing and non habitual chewing FFP and Dentate were similar, R M was less active during chewing and L AT higher during non habitual chewing in Denture than in FFP and Dentate
	B) Denture (21)		
	C) Dentate (21)		
Dellavia et al, 2012[35]	A) FFP/Denture (10)	1) Frequency (Hz) per side	No differences between groups
	B) FFP (8)	2) Total standardised activity (μvV/μV%) per side	Higher activity in patients with FFP and Denture than in Dentate in both sides
	C) Dentate (8)	3) Total standardised activity (μvV/μV%) per cycle and side	Higher activity in patients with FFP and Denture than in Dentate in both sides
		4) Total standardised activity (μvV/μV%) on the working side per side	No significant differences between groups
		5) Confidence ellipse (%) per side	Tendency to larger areas in implant patients than in Dentate (no significance)
		6) SMI	Lower in implant patients but significant differences only between FFP/Denture and Dentate subjects

R = right, L = left; FFP = implant-supported full fixed prosthesis wearers; AT = anterior temporalis muscle; M = masseter muscle.

Study or Subgroup	all fixed			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	83.9	2.4	8	85.3	3.3	8	22.4%	-1.40 [-4.23, 1.43]
Ferrario et al, 2004	86.9	1.3	7	87.5	2.3	5	35.9%	-0.70 [-2.93, 1.53]
Tartaglia et al, 2008	84.89	1.85	5	86.96	1.87	8	41.6%	-2.07 [-4.15, 0.01]
Total (95% CI)			**20**			**21**	**100.0%**	**-1.43 [-2.77, -0.09]**

Heterogeneity: Chi² = 0.78, df = 2 (P = 0.68); I² = 0%
Test for overall effect: Z = 2.09 (P = 0.04)

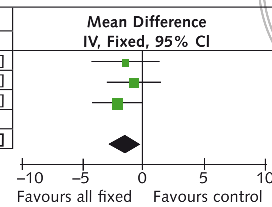

Fig 2 Forest plot of the mean differences in anterior temporalis index of symmetry (POC TA) during maximal voluntary clenching between patients with FFP in both jaws and dentate subjects computed in the three comparable studies[10,35,36]. A significant effect (P = 0.04) is visible: FFP patients have a lower symmetry than reference individuals.

patients than in patients with FFP[36,41], while the remaining papers failed to find significant differences[10,35,37,42,44]. Only three reports compared data from patients treated with FFP, or with overdentures or dentures[36,42,44]. These studies found an overall decrease of muscular activity in subjects with removable prostheses, however only De Rossi et al[42] reported a significant value. The symmetrical pattern of muscular contraction and potential lateral displacing components (i.e. the tendency of the mandible to move toward one side during a symmetric bilateral clenching, caused by unbalanced contractile activity of contralateral masseter and temporalis muscles) were analysed by three trials[10,35,36]. Ferrario et al[36] observed a significantly higher symmetry in muscular activity of dentate and FFP than for overdentures. Tartaglia et al[10] reported an increment of temporalis activity in patients with FFP in both jaws than in dentate subjects, while Dellavia et al[35] did not report any difference.

Chewing

The jaw muscle function during chewing has been analysed in seven cross-sectional studies[10,35,36,38-40,42], one within-subject crossover trial[34] and one longitudinal study[33].

Two studies compared the EMG amplitude of edentulous patients wearing dentures in both jaws or FFP and reported contrasting data[33,42]. Berretin-Felix et al[33] did not find any difference between groups, while De Rossi et al[42] observed a different muscle contraction pattern between groups (higher temporalis than masseter contraction in the denture group, the opposite in FFP group).

Two studies compared data from patients with FFP and with overdentures[34,36], and both reported no significant differences on muscular activity and symmetry between the two prostheses. When patients with FFP were compared with dentate patients, it appeared that:

- neuromuscular coordination is higher in dentate patients than in FFP group[10,35,36]
- two studies reported that the global muscular activity was higher in FFP than in dentate[10,35], while a further two studies did not find differences in EMG amplitude between groups[39,40]
- unlike the FFP group, dentate patients modulate the muscular activity on food hardness (stronger EMG activity with hard food) and during the whole chewing sequence (decreased activity at the end of chewing act)[39,40]
- two studies reported that duration of activity before swallowing was higher in the FFP group than in the dentate group[38,39], while Grigoriadis et al[40] failed to find any difference.

Data analysis

At in-depth evaluation of the parameters reported by the included studies, only three had comparable data that allowed a statistical analysis[10,35,36]. These studies evaluated static and dynamic tasks in edentulous patients restored with FFP in both jaws or with FFP only in the mandible and denture in the maxilla and in a dentate control. For all the comparable parameters, the effect estimates and confidence intervals were computed by forest plot. The following parameters had significant results (Figs 2 to 14):

- Anterior temporal symmetry in maximal voluntary clenching (POC = percentage overlapping coefficient) was lower only in patients with FFP in both arches, compared to dentate.
- Chewing frequency in FFP patients (with FFP in both jaws or only in mandible) was always larger than in dentate.

Study or Subgroup	all fixed			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	1.5	0.1	8	1.3	0.1	8	69.0%	0.20 [0.10, 0.30]
Ferrario et al, 2004	1.4	0.2	7	1.2	0.2	5	12.6%	0.20 [-0.03, 0.43]
Tartaglia et al, 2008	1.32	0.17	5	1.25	0.17	8	18.4%	0.07 [-0.12, 0.26]
Total (95% CI)			**20**			**21**	**100.0%**	**0.18 [0.09, 0.26]**

Heterogeneity: Chi² = 1.47, df = 2 (P = 0.48); I² = 0%
Test for overall effect: Z = 4.24 (P < 0.0001)

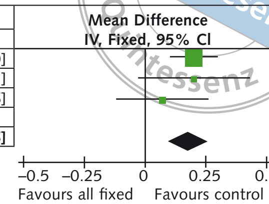

Fig 3 Forest plot of the mean differences in the right side chewing frequency between patients with FFP in both jaws and dentate subjects computed in the three comparable studies[10,35,36]. A significant effect (P < 0.0001) in favour of the dentate subjects is visible.

Study or Subgroup	all fixed			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	1.4	0.2	8	1.3	0.1	8	62.9%	0.10 [-0.05, 0.25]
Ferrario et al, 2004	1.4	0.1	7	1.2	0.3	5	20.2%	0.20 [-0.07, 0.47]
Tartaglia et al, 2008	1.48	0.22	5	1.24	0.33	8	16.9%	0.24 [-0.06, 0.54]
Total (95% CI)			**20**			**21**	**100.0%**	**0.14 [0.02, 0.27]**

Heterogeneity: Chi² = 0.87, df = 2 (P = 0.65); I² = 0%
Test for overall effect: Z = 2.29 (P = 0.02)

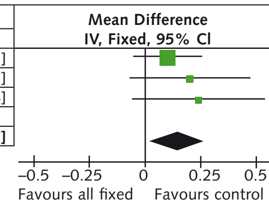

Fig 4 Forest plot of the mean differences in the left side chewing frequency between patients with FFP in both jaws and dentate subjects computed in the three comparable studies[10,35,36]. A significant effect (P = 0.02) in favour of the dentate subjects is visible.

Study or Subgroup	fixed/mobile			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	1.5	0.1	10	1.3	0.1	8	80.7%	0.20 [0.11, 0.29]
Tartaglia et al, 2008	1.24	0.17	5	1.25	0.17	8	19.3%	-0.01 [-0.20, 0.18]
Total (95% CI)			**15**			**16**	**100.0%**	**0.16 [0.08, 0.24]**

Heterogeneity: Chi² = 3.79, df = 1 (P = 0.05); I² = 74%
Test for overall effect: Z = 3.74 (P = 0.0002)

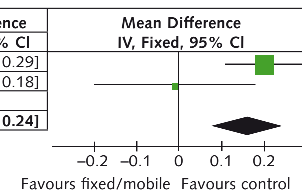

Fig 5 Forest plot of the mean differences in the right side chewing frequency between patients with mandibular FFP and maxillary denture and dentate subjects computed in the three comparable studies[10,35,36]. A significant effect (P = 0.0002) in favour of the dentate subjects is visible.

Study or Subgroup	fixed/mobile			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	1.5	0.1	10	1.3	0.1	8	87.4%	0.20 [0.11, 0.29]
Tartaglia et al, 2008	1.3	0.1	5	1.24	0.33	8	12.6%	0.06 [-0.18, 0.30]
Total (95% CI)			**15**			**16**	**100.0%**	**0.18 [0.10, 0.27]**

Heterogeneity: Chi² = 1.1 0, df = 1 (P = 0.29); I² = 9%
Test for overall effect: Z = 4.11 (P < 0.0001)

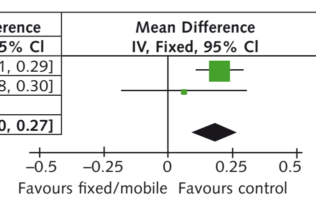

Fig 6 Forest plot of the mean differences in the left side chewing frequency between patients with mandibular FFP and maxillary denture and dentate subjects computed in the three comparable studies[10,35,36]. A significant effect (P < 0.0001) in favour of the dentate subjects is visible.

Study or Subgroup	all fixed			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al 2012	53.7	11.9	8	69.5	9.5	8	83.4%	-15.80 [-26.35, -5.25]
Ferrario et al 2004	28	32.1	7	67.9	16.7	5	11.9%	-39.90 [-67.82, -11.98]
Tartaglia et al 2008	59.25	42.38	5	55.29	34.97	8	4.7%	3.96 [-40.39, 48.31]
Total (95% CI)			**20**			**21**	**100.0%**	**-17.74 [-27.37, -8.10]**

Heterogeneity: Chi² = 3.47, df = 2 (P = 0.18); I² = 42%
Test for overall effect: Z = 3.61 (P = 0.0003)

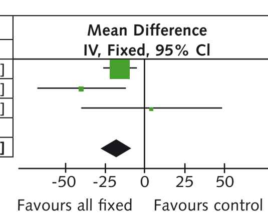

Fig 7 Forest plot of the mean differences in the symmetry masticatory index (SMI) between patients with FFP in both jaws and dentate subjects computed in the three comparable studies[10,35,36]. A significant effect (P = 0.0003) is visible: FFP patients have a lower symmetry than reference individuals during chewing.

Study or Subgroup	fixed/mobile			all fixed				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	31.3	22.2	10	53.7	11.9	8	89.4%	-22.40 [-38.44, -6.36]
Tartaglia et al, 2008	33.76	31.93	5	59.25	42.38	5	10.6%	-25.49 [-72.00, 21.02]
Total (95% CI)			**15**			**13**	**100.0%**	**-22.73 [-37.89, -7.56]**

Heterogeneity: Chi² = 0.02 , df = 1 (P = 0.90); I² = 0%
Test for overall effect: Z = 2.94 (P = 0.003)

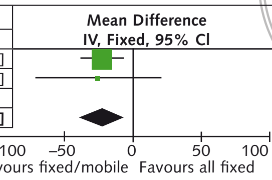

Fig 8 Forest plot of the mean differences in the symmetry masticatory index (SMI) between patients with FFP in both jaws and with mandibular FFP and maxillary denture computed in the three comparable studies[10,35,36]. A significant effect (P = 0.003) is visible: patients with FFP combined with a maxillary denture have a lower symmetry than patients with both FFP during chewing.

Study or Subgroup	fixed/mobile			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	31.3	22.2	10	69.5	9.5	8	85.5%	-38.20 [-53.45, -22.95]
Tartaglia et al, 2008	33.76	31.93	5	55.29	34.97	8	14.5%	-21.53 [-58.55, 15.49]
Total (95% CI)			**15**			**16**	**100.0%**	**-35.78 [-49.88, -21.68]**

Heterogeneity: Chi² = 0.67, df = 1 (P = 0.41); I² = 0%
Test for overall effect: Z = 4.97 (P < 0.00001)

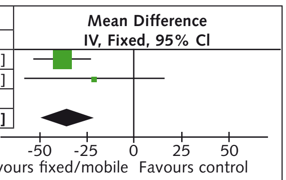

Fig 9 Forest plot of the mean differences in the symmetry masticatory index (SMI) between patients with mandibular FFP and maxillary denture and dentate reference subjects computed in the three comparable studies[10,35,36]. A significant effect (P < 0.0001) is visible: patients with FFP combined with a maxillary denture have a lower symmetry than dentate subjects during chewing.

Study or Subgroup	all fixed			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	1.721	1.211	8	1.04	0.733	8	60.6%	0.68 [-0.30, 1.66]
Ferrario et al, 2004	3.792	2.4	7	0.784	0.363	5	17.9%	3.01 [1.20, 4.81]
Tartaglia et al, 2008	2.55	1.82	5	1.144	0.567	8	21.6%	1.41 [-0.24, 3.05]
Total (95% CI)			**20**			**21**	**100.0%**	**1.25 [0.49, 2.02]**

Heterogeneity: Chi² = 4.97, df = 2 (P = 0.08); I² = 60%
Test for overall effect: Z = 3.22 (P = 0.001)

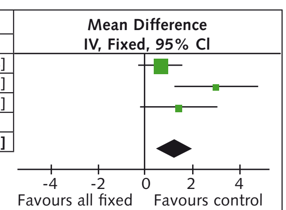

Fig 10 Forest plot of the mean differences in the variability of pattern contraction (confidence ellipse area) during right side chewing between patients with FFP in both jaws and dentate subjects computed in the three comparable studies[10,35,36]. A significant effect (P = 0.001) in favour of the control group is visible.

Study or Subgroup	fixed/mobile			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	3.732	2.335	10	1.04	0.733	8	34.9%	2.69 [1.16, 4.23]
Tartaglia et al, 2008	2.679	1.199	5	1.144	0.567	8	65.1%	1.53 [0.41, 2.66]
Total (95% CI)			**15**			**16**	**100.0%**	**1.94 [1.03, 2.84]**

Heterogeneity: Chi² = 1.42, df = 1 (P = 0.23); I² = 30%
Test for overall effect: Z = 4.20 (P < 0.0001)

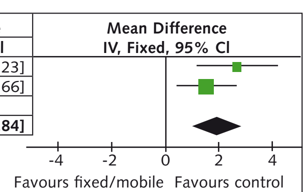

Fig 11 Forest plot of the mean differences in the variability of pattern contraction (confidence ellipse area) during right side chewing between patients with mandibular FFP and maxillary denture and dentate subjects computed in the three comparable studies[10,35,36]. A significant effect (P < 0.0001) in favour of the control group is visible.

Study or Subgroup	all fixed			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al 2012	1.481	0.51	8	0.933	0.395	8	82.4%	0.55 [0.10, 1.00]
Ferrario et al 2004	2.576	1.437	7	1.372	1.084	5	8.1%	1.20 [-0.22, 2.63]
Tartaglia et al 2008	2.998	1.423	5	1.077	0.607	8	9.5%	1.92 [0.60, 3.24]
Total (95% CI)			**20**			**21**	**100.0%**	**0.73 [0.33, 1.14]**

Heterogeneity: Chi² = 4.21, df = 2 (P = 0.12); I² = 52%
Test for overall effect: Z = 3.53 (P = 0.0004)

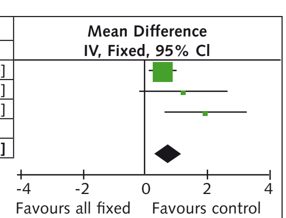

Fig 12 Forest plot of the mean differences in the variability of pattern contraction (confidence ellipse area) during left side chewing between patients with FFP in both jaws and dentate subjects computed in the three comparable studies[10,35,36]. A significant effect (P = 0.0004) in favour of the control group is visible.

Study or Subgroup	fixed/mobile			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	3.307	1.73	10	0.933	0.395	8	76.0%	2.37 [1.27, 3.48]
Tartaglia et al, 2008	3.144	2.192	5	1.077	0.607	8	24.0%	2.07 [0.10, 4.03]
Total (95% CI)			**15**			**16**	**100.0%**	**2.30 [1.34, 3.26]**

Heterogeneity: Chi² = 0.07, df = 1 (P = 0.79); I^2 = 0%
Test for overall effect: Z = 4.67 (P < 0.0001)

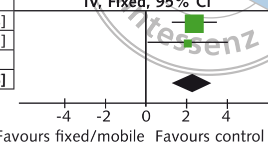

Fig 13 Forest plot of the mean differences in the variability of pattern contraction (confidence ellipse area) during left side chewing between patients with mandibular FFP and maxillary denture and dentate subjects computed in the three comparable studies[10,35,36]. A significant effect (P < 0.00001) in favour of the control group is visible.

Study or Subgroup	fixed/mobile			Control				Mean Difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Dellavia et al, 2012	3.307	1.73	10	1.481	0.51	8	80.5%	1.83 [0.70,2.95]
Tartaglia et al, 2008	3.144	2.192	5	2.998	1.423	5	19.5%	0.15 [-2.14, 2.44]
Total (95% CI)			**15**			**13**	**100.0%**	**1.50 [0.48, 2.51]**

Heterogeneity: Chi² = 1.66, df = 1 (P = 0.20); I^2 = 40%
Test for overall effect: Z = 2.90 (P = 0.004)

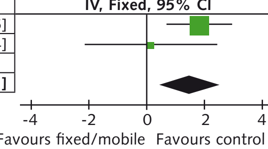

Fig 14 Forest plot of the mean differences in the variability of pattern contraction (confidence ellipse area) during left side chewing between patients with mandibular FFP and maxillary denture and patients with FFP in both jaws computed in the three comparable studies[10,35,36]. A significant effect (P = 0.004) in favour of the FFP/FFP group is visible.

- Masticatory symmetry during chewing (SMI = symmetry masticatory index) in subjects with FFP in both jaws was smaller than in dentate and larger than in subjects with FFP only in the mandible.
- Variability of contraction pattern during chewing (confidence ellipse area) in subjects with FFP in both jaws was larger than in dentate and smaller than in subjects with FFP only in the mandible except for right side mastication (P = 0.06).

The following parameters resulted in not being deemed significant:

- Masseter symmetry in maximal voluntary clenching (POC = percentage overlapping coefficient) between all groups.
- Activity standardised in maximal voluntary clenching between all groups. Even if the remaining 13 trials analysed the same tasks, differences in the parameters, study population and study design, did not allow to perform any statistical comparison. In particular, the following variables were found:
  - study population: different age, control patients with different dental situations (dentate, dentate with partial bridges…)
  - prosthetic treatment performed (i.e. different antagonist, number of implants supporting the full-fixed prosthesis, materials used to realise the prosthesis), and surgical protocols (i.e. tilted or axial implants)
  - follow-up
  - electromyographic parameters evaluated
  - experimental protocols (i.e. different force used to induce reflex)
  - analysed muscles
  - recording of standardised or non-standardised signals.

Discussion

The aim of the present review was to evaluate the function of jaw muscle in response to occlusal rehabilitation performed with a full fixed prostheses on a limited number of implants.

To investigate this topic, the authors mostly designed cross-sectional observational studies, and all but one paper used electromyography to directly measure muscular activity. Furthermore, muscular function was analysed following specific tasks for statics (clenching, swallowing, reflex and fatigue) and dynamics (chewing). In the present review, the selected records were pooled and reported following these tasks; furthermore a statistical analysis was performed for the resulting data that were comparable between studies.

Briefly, fatigue was analysed in two studies[32,44]. Results indicate a similar behaviour in dentate and FFP patients, except for a significant downward trend of the mean power frequency that was observed in dentate but not in FFP patients. Patients with FFP expressed a fear of biting too hard and fracturing the prosthesis, thus modifying the real maximal clenching output performed by subjects and the related MPF signal.

The reflex is a protective masticatory function resulting in a decreased EMG activity that suddenly arrests jaw-closing movements before tooth contact when a hard object occurs between teeth, thus preventing large forces exerting on teeth[47,48]. Results reported by studies evaluating reflexes seem to support the idea that reflex generation is mainly due to periodontal mechanoreceptors, and also mucosal receptors participate at this function[43,45,46]. In contrast, inner ear receptors may be excluded for this physiological activity[43,45].

From studies evaluating the swallowing task, it may be concluded that stabilisation of occlusion by anchoring prostheses on implants reduces the muscular activity required during swallowing, thus making the masticatory system more efficient[33,38].

The maximum voluntary clenching force is largely used to measure the isometric muscle activity, symmetry, the balanced and standardised contractile activity. It was evaluated in seven studies[10,35-37,41,42,44]. Even if some conflicting data emerge from studies on clenching, all authors agree that subjects with FFP have a global neuromuscular equilibrium and that the EMG contraction patterns are similar to those observed in dentate subjects.

The jaw muscle function during chewing has been analysed in nine studies[10,33-36,38-40,42]. From the studies that tested chewing activity by means of foods with different textures, it emerges that masticatory function is adjusted and EMG pattern is typical for each food[33,34,40]. Even if some conflicting data exist between trials, studies converge on the substantial conclusion that muscular function in subjects with FFP still has some impairment during chewing when compared to dentate patients.

The main fact that arises from this review is the considerable heterogeneity on evaluated parameters for each task and the different study populations among the studies.

The interval time elapsing between prosthetic rehabilitation and data collection also varied considerably among studies. However, this is an essential variable that should be standardised, since studies reported that in patients rehabilitated by oral implants, neuromuscular adaptation takes few months to recover[49,50]. Haraldson and Ingervall[38] also found that the number of years of wearing maxillary FFP was positively correlated to the number of chewing cycles. Furthermore, the age of control patients should be similar to that of treated patients, since the muscular function may be impaired in old patients[51]. Considering the high variability among the included studies, it was not possible to statistically compare data from most trials, with the exception of three studies performed by the same research group[10,35,36]. Data reported from De Rossi et al[42] seemed to be comparable. However, at deeper evaluation of the presented data, non-standardised values were reported; therefore it was not included in this comparison.

A further important element that needs to be considered is that several studies were designed and conducted some decades ago (in the 1970s to 1990s)[32,34,37-39,43-46]; surgical protocols as well as prosthetic design and materials have changed much over the years.

Studies on mechanical signal transduction report that periodontal ligament mechanoreceptors are mostly sensitive to force direction[52] and have the highest sensitivity to change during the appliance of static forces at a very low level (1 N). In particular, anterior teeth seem to be much more sensitive to low forces than posterior teeth[53]. During chewing, periodontal receptors provide information to the sensorimotor cortex on the contact state between food and teeth, on direction of tooth loading and on food texture. After tooth extraction, these mechanoreceptors are lost thus inducing significant changes in jaw or tongue motor representation in the facial sensorimotor cortex (for review see Trulsson et al[54] and Lobbezoo et al[55]). Furthermore, subjects without periodontal receptors loose the ability to perceive force changes; they apply high hold forces and are disturbed in the control of precisely directed and low biting forces. In edentulous patients restored with complete denture or overdenture, the mucosal receptors are activated by the contact with the prosthesis and generate a sort of mechanical signal that provides information about movements and pressure[45]. In edentulous patients restored with full fixed prosthesis on implants, the mucosal receptors are not activated by the prosthesis; however a sensory awareness, called osseoperception, intervenes. The osseoperception is the perception of mechanical stimuli that are transmitted from the prosthesis throughout the implants to the mechanical receptors within the bone, the periosteum, the mucosa, or to the spindle of muscles and capsular receptors of the joint[55]. The papers selected in the present review reveal that edentulous subjects rehabilitated with FFP have in statics a muscular function resembling that observed in dentate controls. On the other hand, in dynamic tasks the neuromuscular system seems to be less efficient, coordinated and equilibrated. Osseoperception seems to be more efficient on the perception of forces loading the structures, while it may be less sensitive to force direction thus resulting in uncoordinated movements, higher muscular activity and expenditure of energy with higher fatigue than in dentate patients.

As result of our research, we only found trials testing muscular function of patients with complete dentures, overdentures and FFP on a limited number of implants compared to dentate. No articles comparing patients with FFP supported by a limited number of implants and patients with FFP supported by a large number of implants were found.

Since the implant loading seems to increase the density of nerve fibres in peri-implant tissues[56], it could be interesting to assess if a large number of implants may stimulate the post-loading re-innervation, thus improving the osseoperception and muscular function.

In conclusion, the presently available literature indicates that prostheses supported by a limited number of implants offers a satisfying jaw function. This should be seen against the surgical risk/biological cost of a surgical intervention for bone augmentation/regeneration.

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