Classification methods for human masticatory muscle fibers: critical literature review

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Abstract

To carry out a literature review of classification methods based on anatomical, physiological and histochemical characteristics of human masticatory muscle fibers. Search on *PubMed*, *Web of Science*, *BBO (Brazilian Odontology Library)*, *LILACS* and *MEDLINE* databases using keywords in English without time restrictions. The most cited classification was Brooke and Kaiser's (1970) histochemical method. Prevalence of type I, II, and IIB fibers: masseter muscle-35 to 72.8% (type I), 48 to 65% (type II), and 19.3 to 43.1% (type IIB); temporal muscle-27 to 75% (type I), 52 to 73% (type II), and 44.8 to 56.5% (type IIB); lateral pterygoid muscle-35 to 72.1% (type I) and 27 to 65% (type II); medial pterygoid muscle-37 to 64.5% (type I) and 33 to 56% (type II). There were differences between individuals with normal intermaxillary relationship and others with altered facial dimensions. Intermediate fibers ranged from 1% (temporal and masseter muscles) to 20% (medial pterygoid muscle) in normal dentition, and from 4% (temporal muscle) to 19% (masseter muscle) in denture wearers. As to the diameter, type I fibers (masseter muscle) ranged from 19 to 40 µm in men and from 27 to 45 µm in women; in the temporal muscle, type I fibers had a mean diameter of 44 µm; in the lateral and medial pterygoid muscles, type I fibers ranged from 29.3 to 42.1 µm. Comparatively, type I fibers had a greater diameter than intermediate and type II fibers.

Keywords: classification, humans, masticatory muscles, muscle fibers.

1 Introduction

Mastication is promoted by the masseter, temporal, and medial and lateral pterygoid muscles. The masseter is divided into superficial (which determines mandibular protrusion) and deep (mandibular retractor) parts, and together they raise the mandible. The temporal muscle is divided into anterior (stronger, which raises the mandible) and posterior (responsible for mandibular retraction and lateralization) parts (KIRKEBY and GARBARSCH, 2001; MADEIRA and RIZZOLO, 2006). The lateral pterygoid muscle protrudes the mandible by means of the superior and inferior heads; the superior head stabilizes the articular disk and controls the return speed of the mandible head to the mandibular fossa. The medial pterygoid muscle works as a synergist of the masseter muscle potentiating mandibular elevation and protrusion (MADEIRA, 2004).

Skeletal striated fibers vary in type and frequency for the same muscles of different species, for different muscles of the same specie and in muscle fibers of the same muscle according to growth, age, eating habits, ethnical group, physical activity, gender, genetic, hormones and innervation factors (FERRARI, 1994). In skeletal muscle fibers, there is a dynamic status which ranges according to the functional demand, hormonal changes and innervation with increased oxidative capacity in postnatal life (STARON, 1997). Of these factors, although there is a marked genetic influence during fetal development and possibly during the early after birth period, the major factor in the differentiation of muscle fibers results from the nervous activity that activate them (SIECK and PRAKASH, 1997).

The mammalian skeletal striated muscle tissue is basically made up of red, white and intermediate fibers (CLOSE, 1972), which are histochemically classified into type I or red fibers, type IIB and IIC or white fibers and type IIA and IIAB or intermediate fibers (BROOKE and KAISER, 1970; KORFAGE, KOOLSTRA, LANGENBACH et al., 2005; SCIOTE and MORRIS, 2000). The temporal muscle has a larger amount of white fibers whereas the masseter is composed of mostly red fibers. Muscle fiber types may also be determined according to the activity of myofibrillar ATPase (based on human biopsy studies), and are divided into type I fibers (with low ATPase activity) and type II fibers, with increased enzymatic activity (ENGEL, 1998; SOTGIU, CANTINI, ROMAGNOLI et al., 2002).

As to the contraction speed, intermediate fibers may be classified into fast-twitch-red fibers, slow-twitch-intermediate fibers or fast-twitch-white fibers (BARNARD, EDGERTON, FURUKAWA et al., 1971). With glycogen quantification and the quantification of several enzyme activities, the terminology of fast-twitch-white fibers was changed into fast-twitch-glycolytic (FG) fibers, fast-twitch-red fibers into fast-twitch-glycolytic-oxidative fibers (FOG) and slow-twitch-intermediate into slow-twitch-oxidative or SO. FG fibers have a high glycogen content, low cytochrome concentration and low anaerobic activity; FOG fibers have a high cytochrome content with moderate to high anaerobic and oxidative activity and SO muscle fibers have a low glycolytic enzyme content and moderate to high aerobic capacity (PETER, BARNARD, EDGERTON et al., 1972).

In addition to the several classification methods for human muscle fibers, since the discovery of reciprocal relationships between phosphorilase and oxidative enzyme activities, a classification of type I fibers (with high oxidative and low glycolytic activity) and type II fibers (with low oxidative and high glycolytic activity) has been proposed, although intermediate fibers were included (DUBOWITZ, 1965).

The objective of the present study is to carry out a literature review of classification methods based on anatomical, physiological and histochemical characteristics for human masticatory muscle fibers.

2 Material and methods

PubMed, *Web of Science*, *BBO (Brazilian Odontology Library)*, *LILACS* and *MEDLINE* databases were used as search reference performed in two steps using keywords in English and no time restrictions. In the first systematization, papers on classification methods for skeletal striated muscle fibers were searched, using the keywords "fiber", "type" and "muscle", by randomized combination until these three terms were included.

In the second step, papers exclusively on fiber types present in human masticatory muscles were searched, using the keywords "method", "classification", "fiber", "type", "mastication", "masticatory", "muscle", "human", "masseter", "temporal", "lateral pterygoid", "medial pterygoid", "jaw", "property", "characteristic", "histochemical", "physiologic" and "anatomical", by randomized combination, until all keywords were included. The obtained manuscripts were selected according to the mention of histochemical, anatomical and physiological characteristics, in a total of 48 papers (*MEDLINE*: 26, *PubMed*: 18, *Web of Science*: 4, and *BBO* and *LILACS*: none). Of these, 23 were considered satisfactory as to the impact index, sample size, method description, result display and organization, relevance, ethics and coherence among title, objectives and conclusions. Relevant histochemical, anatomical and physiological characteristics of masticatory muscles included types, diameter, percentage and distribution of muscle fibers in individuals with natural dentition or in prosthesis users, differences related to gender and the presence of intermediate fibers.

3 Results

The most cited classification for muscle fibers in humans was Brooke and Kaiser's histochemical method, 1970 (Table 1). There was a prevalence of type I, II and IIB fibers in the masseter and temporal muscles, ranging from 35 to 72.8% (type I), 48 to 65% (type II) and 19.3 to 43.1% (type IIB) for the masseter muscle and 27 to 75% (type I), 52 to 73% (type II) and 44.8 to 56.5% (type IIB) for the temporal muscle (Table 2). In the lateral and medial pterygoid muscles type I and II fibers prevailed, with respective values of 35 to 72.1 and 27 to 65% for the lateral pterygoid muscle and 37 to 64.5% and 33 to 56% for the medial pterygoid muscle (Table 3). In individuals with normal intermaxillary relationship, type I fibers ranged from 14 to 62.3% (masseter muscle) and 35 to 61% (temporal muscle) whereas type II ranged from 21.9 to 79% (masseter muscle) and 35 to 65% (temporal muscle). In individuals with facial dimensions alterations, type I fibers ranged from 28.6 to 51.9% (masseter muscle) whereas type II fibers ranged from 32 to 57.2% (masseter muscle). (Table 4). In individuals with normal dentition, intermediate fibers (IM) ranged from 1% (temporal and masseter muscles) to 20% (medial pterygoid muscle) (Tables 2,3) and in adult denture wearers they ranged from 4% (temporal muscle) to 19% (masseter muscle) (Table 4). As to the diameter, type I fibers in the masseter muscle ranged from 19 to 40 μm in men and from 27 to 45 μm in women; in the temporal muscle, type I fibers had a mean diameter of 44 μm; in the lateral pterygoid muscle, type I had 42.1 μm in men and 38.1 μm in women; and in the medial pterygoid muscle, type I ranged from 29.3 to 42 μm (Tables 5,6). Comparatively, type I fibers had a greater diameter than intermediate fibers, which had in turn, a greater diameter than type II fibers (Tables 5,6).

4 Conclusion

Muscle fiber classifications based on the association of histochemical, anatomical and physiological criteria have been well accepted. However, experimental studies have shown that classifications based only on structural or functional properties (such as fast or slow fibers, white, intermediate or red fibers, A, B or C and type I or II fibers) are not complete enough, and should be included in a multiple and broader classification system, which would give emphasis to the interaction of more than one variable (SCHIAFFINO and HANZLIKOVA, 1970). There are in vivo limitations regarding the activity of myofibrillar ATPase activity, and intermediate muscle fibers may present characteristics of red or white fibers due to the reaction time, and differences in the concentration of hydrogen ions (CLOSE, 1972; KIRKEBY and GARBARSCH, 2001).

Table 1 shows how each muscle fiber reacts to pre-incubation at a specific pH and it also shows that morphohistochemical characteristics correlate with functional properties of the muscle. Thus, white fibers have a fast-twitch and are preferably recruited for large intensity and short duration activities, similarly to the temporal muscle in dental occlusion. On the other hand, red fibers have a slow-twitch, required for long duration and resistance activities, such as the work of the masseter muscle in prolonged bites (SOTGIU, CANTINI, ROMAGNOLI et al., 2002). Electromyography studies of the masseter muscle indicate that type I fibers (which are the majority) belong to motor units characterized by low threshold and slow-twitch, whereas type II fibers have a high threshold and fast-twitch. In the temporal muscle, although there is a prevalence of type I fibers, there is a remarkable amount of type II fibers due to its function, related to motor units associated to high threshold and fast-twitch (STALBERG, ERIKSSON, ANTONI et al., 1986).

Histochemical techniques results may vary considerably, once their reactions may take weeks, and minimal pH changes (as low as 0.1) are referred as significant (WERNECK, 1981). In analysis of human and rodent muscle fibers by pre-incubation and pH ranging from 3.9 to 9.4 (BROOKE and KAISER, 1970), histochemical results (shown in Table 1) corroborate the anatomical classification of Edgerton and

Table 1. Main histochemical classification for masticatory muscle fibers (BROOKE and KAISER'S, 1970) and comparison with other classification systems.

Brooke and Kaiser's classification (1970)						Other classifications		
Fiber type	ATPase pH 9.4	SDH	Inhibition with ATPase pH 4.7	Inhibition with ATPase pH 3.9	Contraction type	Physiological (PETER et al., 1972)	Physiological (BURKE et al., 1971)	Anatomic (EDGERTON-SIMPSON, 1969)
I	Mild	-	-	-	Mild and continuous	SO	S	Red
IIA	Strong	Moderate to strong	-	-	Fast	FOG	FR	Intermediate/white
IIB	Strong	mild	-	-	Fast	-	FF	White
IIAB	Strong	-	-	-	Fast	FG	FI	-
IIC	Strong	-	Mild	Complete	Fast	-	-	White

Legend: SDH = succinate dehydrogenase; SO = slow oxidative; S = slow; FOG = fast-twitch-glycolytic-oxidative; FG = fast-twitch-glycolytic; FR = fast-resistant; FF= fast; FI = fast intermediate; and (–) = not reported.

Table 2. Percentage of masseter and temporal muscle fibers according to age or muscular part in individuals with normal dentition.

Author	Masseter muscle (%)						Temporal muscle (%)					
	I	IM	II	IIA	IIB	IIC	I	IM	II	IIA	IIB	IIC
Vignon et al. (1980)	35	-	65	-	-	-	27	-	73	-	-	-
	49	1	50	-	-	-	-	-	-	-	-	-
	40	12	48	-	-	-	43	5	52	-	-	-
	41	5	54	-	-	-	37	1	62	-	-	-
Eriksson and Thornell (1983)	67.3	7.6	-	-	25.1	-	50.4	4.8	-	-	44.8	-
	49.8	3.5	-	3.6	43.1	-	40.2	2.3	-	1.0	56.5	-
	72.8	6.8	-	1.1	19.3	-	75	10	-	15	45.9	-
	68.7	5.2	-	5.5	20.6	-	48.2	5.9	-	-	-	-

Table 3. Percentage of lateral and medial pterygoid muscle fibers according to age or muscular part in individuals with normal dentition.

Author	Lateral pterygoid muscle (%)						Medial pterygoid muscle (%)					
	I	IM	II	IIA	IIB	IIC	I	IM	II	IIA	IIB	IIC
Vignon et al. (1980)	35	-	65	-	-	-	47	20	33	-	-	-
	52	2	46	-	-	-	37	7	56	-	-	-
	57	16	27	-	-	-	-	-	-	-	-	-
	39	12	49	-	-	-	-	-	-	-	-	-
Eriksson et al. (1981)	66	12.5	-	-	15.7	5.8	-	-	-	-	-	-
	72.1	14.2	-	-	8.1	5.6	-	-	-	-	-	-
Eriksson and Thornell (1983)	-	-	-	-	-	-	64.5	8	-	-	27.5	-
	-	-	-	-	-	-	45.9	8.8	-	-	-	-

Simpson (1969). However, there is difficulty to standardize the terminology when classifying all the different types of muscle fibers. On the other hand, Brooke and Kaiser's histochemical classification (1970) has been broadly used, despite the existence of other classification methods for muscle fibers (BURKE, LEVINE and ZAJAC, 1971; EDGERTON and SIMPSON, 1969; KIRKEBY and GARBARSCH, 2001; KORFAGE, KOOLSTRA, LANGENBACH et al., 2005; PETER, BARNARD, EDGERTON et al., 1972).

Histochemical analysis has shown that type II fibers are predominant in the masseter and temporal muscles of adult individuals, whereas in young individuals type I fibers and lower diameter of type IIB fibers prevail, even though most diameters in all fiber types in young individuals is significantly greater when compared to the diameter of fibers in adults (MONEMI, KADI, LIU et al., 1999; RINGQVIST, 1971). Table 4 shows that in individuals with normal intermaxillary relationship, types I and II fibers (temporal muscle) present no relevant difference; whereas in masseter muscle, type II fibers are predominant in relation to type I. In individuals with altered facial dimensions, data are related only to masseter muscle and type II fibers are predominant in relation to type I.

Studies on the behavior of intermediate fibers of the human masseter muscle using myofibrillar reaction with ATPase have shown difficulties to determine whether inter-

Table 4. Percentage of masseter and temporal muscle fiber types according to intermaxillary relationship in denture wearers.

Author	Intermaxillary relationship	Masseter muscle						Temporal muscle				
		I	IM	II	IIA	IIB	IIC	I	IM	II	IIA	IIB
Ringqvist (1971)	Normal	-	-	65	-	-	-	-	-	65	-	-
Ringqvist (1973;1973)	Prognathic	-	1-45	-	-	-	-	-	-	-	-	-
	Normal	26	16	58	-	-	-	-	-	-	-	-
Ringqvist (1974)	Normal	-	-	-	-	-	-	35-61	4	35	-	-
	Prognathic	28.6	14.2	57.2	-	-	-	-	-	-	-	-
Ringqvist et al. (1982)	Normal	14-44	7-19	37-79	-	-	-	-	-	-	-	-
Boyd et al. (1984)	Vertical maxillary excess	51.9	25.6	-	22.5	-	-	-	-	-	-	-
Boyd et al. (1989)	Vertical maxillary excess	50	18	32	-	-	-	-	-	-	-	-
Tuxen et al. (1999)	Normal	♂ 37.1	0.5	62.3	-	-	-	-	-	-	-	-
		♀ 62.3	15.8	21.9	-	-	-	-	-	-	-	-

Legend: ♂ = men; and ♀ = women.

Table 5. Diameter (in µm) of the masseter and temporal muscle fibers according to gender.

Muscle	Masseter						Temporal					
Type of fiber author	I	IM	II	IIA	IIB	IIC	I	IM	II	IIA	IIB	IIC
Ringqvist (1971)	♂ 19-40	-	12-40	-	-	-	-	-	-	-	-	-
	♀ 27-45	-	11-35	-	-	-	-	-	-	-	-	-
Ringqvist (1973)	33	23	16	-	-	-	-	-	-	-	-	-
Vignon et al. (1980)	38.4	34.2	16.1	-	-	-	35.0	34.0	18.3	-	-	-
Eriksson and Thornell (1983)	44	31	-	39	25	29	44	30	-	38	26	28
Tuxen et al. (1999)	♂ 28	26	31	-	-	-	-	-	-	-	-	-
	♀ 30	28	24	-	-	-	-	-	-	-	-	-

Legend: ♂ = men; and ♀ = women.

Table 6. Diameter (in µm) of the lateral and medial pterygoid muscle fibers according to gender.

Muscle	Lateral pterygoid						Medial pterygoid					
Type of fiber author	I	IM	II	IIA	IIB	IIC	I	IM	II	IIA	IIB	IIC
Vignon et al. (1980)	40.6	30.8	18.6	-	-	-	29.3	25.8	16.4	-	-	-
Eriksson et al. (1981)	♂ 42.1	31.8	-	-	36.8	28.9	-	-	-	-	-	-
	♀ 38.1	25.0	-	-	19.7	20.4	-	-	-	-	-	-
Eriksson and Thornell (1983)	40.6	30.8	18.6	-	-	-	42	29	-	-	32	31

Legend: ♂ = men; and ♀ = women.

mediate fibers are an integral part of the muscle or whether they result from functional alterations due to the high adaptation capability of masticatory muscle fibers (KORFAGE, KOOLSTRA, LANGENBACH et al., 2005). Once muscle cells continuously change themselves to adapt to functional demands, type I fibers seem to transform into type II fibers and vice-versa, and the presence of intermediate fibers may indicate functional alterations of the muscle resulting from abnormal intermaxillary relationship (RINGQVIST, RINGQVIST, ERIKSSON et al., 1982; RINGQVIST, 1973) or a high potential of individual variability in the composition of masticatory muscle fibers (KORFAGE, KOOLSTRA, LANGENBACH et al., 2005).

In healthy individuals and prognathic individuals with staining of the masseter muscle fibers by ATPase (pH 9.4) and NADH2 histochemical methods, the approximate percentage of muscle fibers found is 26% for type I fibers, 58% for type II fibers and 16% of intermediate fibers (RINGQVIST, 1973). In a histochemical study of the masseter muscle after corrective surgery for vertical maxillary excess, SO fibers had a larger diameter and were predominant (SO: 51.9, FG: 25.6 and FOG: 22.5%), and in FG fibers it was possible to detect cytoarchitecture changes in 35% of the cases, consistent with muscular necrosis and fagocytosis. However, such alterations and the pattern of SO fiber prevalence in individuals with vertical maxillary excess may be different from that observed in individuals without craniofacial abnormalities (BOYD, GONYEA, LEGAN et al., 1989).

As to the diameter of the masticatory fibers, although Tables 5,6 show that type I fibers have a greater diameter than intermediate fibers, which in turn have greater diameter than type II fibers, it is also possible to conclude that there are overlapping intervals for each type of muscular fiber, which suggests that the diameter of muscle fibers alone does not allow to differentiate the different fibers (VIGNON, PELLISSIER and SERRATRICE, 1980). When gender is taken into consideration, type II fibers have a statistically significant greater diameter in men than in women, with a consequent more intense bite force evidenced by the greater amount of type II fibers in the anterior area (RINGQVIST, 1971; TUXEN, BAKKE and PINHOLT, 1999; VIGNON, PELLISSIER and SERRATRICE, 1980).

In prognathic patients without significant bad occlusion, the diameter of type II fibers is related to the maximum voluntary isometric contraction and to the force power of the human masseter muscle. There is also a positive association between the diameter of type II fibers and the bite force, but this is not true for the diameter of type I fibers or intermediate fibers, suggesting that type II fibers are essential for intensive bite efforts (SCIOTE and MORRIS, 2000). On the other hand, the percentage of fiber type distribution is not statistically significant for the bite force (RINGQVIST, 1973). There have been attempts to correlate the intermaxillary relationship and the distribution of fibers in the masticatory muscles (Table 4), even though patients with craniofacial morphology abnormalities do not have significant differences in fiber type distribution when compared to normal individuals, suggesting that further studies are required (BOYD, GONYEA, FINN et al., 1984; SHAUGHNESSY, FIELDS and WESTBURY, 1989).

When the masticatory muscles are compared (Tables 2,4), it may be concluded that there is a prevalence of type I fibers in all four muscles, since they have the same embryonary origin, the same nervous supply (the trigeminal nerve) and are synergist in terms of function. The prevalence of type I fibers also indicates the congenital ability of masticatory muscles to promote resistance during continued efforts with a relatively low force, including the stabilization of the articular disk in the temporomandibular joint (ERIKSSON, ERIKSSON, RINGQVIST et al., 1981; ERIKSSON and THORNELL, 1983; MONEMI, KADI, LIU et al., 1999; STAL, 1994).

The most cited classification of human masticatory muscle fibers is Brooke and Kaiser's (1970) histochemical method. Type I fibers are the most frequent fibers in all masticatory muscles in cases of normal dentition; in denture wearers with normal intermaxillary relationship, type I and II fibers are prevalent in the masseter and temporal muscles. The diameter of type I fibers ranges from 19 μm (minimal value for the masseter muscle in men) to 45 μm (maximum value in the masseter muscle in women); type I fibers have greater diameter than intermediate and type II fibers.

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