Hernia (2012) 16:9–20
DOI 10.1007/s10029-011-0868-z

REVIEW

Classification of prosthetics used in hernia repair based on weight and biomaterial

A. Coda · R. Lamberti · S. Martorana

Received: 5 November 2010 / Accepted: 22 July 2011 / Published online: 12 August 2011

Abstract
Purpose The aim of this study was to classify the polymeric prosthetics used for hernia repair based on biomaterial composition and weight in an effort to clarify to surgeons what kinds of material they are dealing with and to provide a standardized system of categorization.
Materials and methods An intensive research effort was carried out on prosthetics that are commercially available worldwide. We conducted a search of the medical literature and companies' websites to find the weights and thicknesses of commercially available prosthetics. Where these data were lacking, we contacted manufacturers directly in order to render the research more complete. A total of 166 products were considered for classification based on biomaterial properties. Among these, a homogeneous group of 80 polypropylene monofilament knitted or woven prosthetics was selected for classification based on weight. Weights were provided for 70 prosthetics (87%), and both the weight and thickness was provided for 40 prosthetics (50%).
Results Classification based on weight: Ultra-light <35 g/m^2, Light $\geq 35 < 70$ g/m^2, Standard $\geq 70 < 140$ g/m^2, Heavy ≥ 140 g/m^2. Classification based on biomaterial composition: simple (prosthetics made of one pure biomaterial); composite (prosthetics made of two or more different layers); combined (prosthetics made of two materials knitted or woven together); and biologic.
Conclusion Weight and biomaterial classifications were proposed after an extensive analysis of commercially available prosthetics. The need for a common terminology is important to avoid misunderstandings among clinicians and technicians.

Keywords Prosthetic · Classification · Weight · Biomaterial · Common language

Introduction

Hernia prosthetics were first manufactured in 1935 when Nylon, the trade name for Polyamide, was discovered. It was the first polymer synthesized and the first purely synthetic fiber. As early as 1942, Melick [1] reported the use of Nylon as suture material. The first reports in which Nylon was used as a prosthetic are by Aquaviva and Bounet of Marseille [2] and Maloney et al. [3].

In 1941, Polyethylene Terephthalate (PET), also known by its brand name, Dacron, was patented in the United Kingdom. Soon after, in 1954, the Italian chemist Giulio Natta, and his German colleague, Karl Ziegler, discovered Polypropylene (PP), the discovery of which won the two researchers the Nobel Prize in Chemistry in 1961.

In France, Nylon and Dacron were immediately adopted for the use of prosthetics in hernia repair; however, in the United States, Francis Usher first chose Dacron [4, 5] and changed to PP in 1963 [6].

With these developments, the dawn of biomaterials in hernia surgery passed into the daylight.

Until about 15 years ago, Nylon was used only in the UK, and surgeons could choose among a few prosthetics manufactured with PP or PET, all of which were quite similar [7]. In the late 1990s, the number of companies

A. Coda (✉)
Surgical Department, Clinica Cellini, Turin, Italy
e-mail: andrea.coda@hernia-repair.it

R. Lamberti · S. Martorana
Herniamesh S.r.l., Chivasso, Turin, Italy

offering prosthetics increased, and they began producing many different kinds of products, most of which were made of PP—the most popular material. At the turn of the twenty-first century, surgeons realized that it would be better if they reduce the weight of the prosthetic, which would leave less foreign material in the body [8].

The aim of this paper is to classify the prosthetics used in hernia surgery based on their weights and the biomaterials from which they are manufactured. We hope that this classification will clarify to surgeons what kind of materials they are dealing with and provide an easier understanding of the products by using a standardized system of categorization.

Materials and methods

An extensive research study was carried out on prosthetics that are available commercially worldwide. We focused on prosthetics that are either flat or shaped in various manners to obtain a device, but we did not consider three-dimensional, anatomically shaped prosthetics or plugs. In addition, barrier films, prostheses with flaps or positioning pockets as well as all products made completely of biological materials were excluded from the study.

Though there is also some literature regarding the use of mosquito net for hernia repair, its use concerns only the absolute need to repair hernias in very poor countries [9–11]. Since the aim of this study is to classify hernia prosthetics available on the market and approved by the competent authorities, mosquito nets are not included in this category here.

We searched the medical literature (Table 1) and company websites to identify weights, materials, and thickness values. To gain a complete overview of the market for prosthetics, a total of 37 websites from medical companies were reviewed (Table 2) and, where data were lacking, we contacted the manufacturers directly in order to render the research more complete. Table 3 shows a list of 19 manufacturers with those who answered providing the requested information (9 companies), those who did not answer (9 companies), and the one who answered refusing to give the information requested.

A total of 166 products were categorized. In some cases, there were discrepancies between the literature and the information on company websites regarding the data

Table 1 List of products for which data have been obtained from the medical literature

Company name	Product
Atrium	PROLITE [8]
Bard	BARD MESH [14]
DiPro Med	EVOLUTION [15]
Ethicon	PROLENE [12, 16–21, 24]
	ULTRAPRO [12–14, 16, 22–25]
	VYPRO [8, 12, 16, 26]
	VYPROII [12, 16, 18]
	PROLENE SOFT [13]
GFE (pfm)	TiMESH XLT [18, 27]
Mpathy/Mast	MINIMESH/HERNIA MESH [28]

Table 2 Websites of prosthetic manufacturers

Website address
1. http://www.abiss.fr
2. http://www.adriamedical.com
3. http://www.ami.at
4. http://www.angiologica.com
5. http://www.aspide.com
6. http://www.assuteurope.com
7. http://www.atriummed.com
8. http://www.davol.com
9. http://www.bbraun.com
10. http://www.corybros.co.uk
11. http://www.cousin-biotech.com
12. http://www.covidien.com/hernia
13. http://www.dipromed.eu
14. http://www.ethicon.com
15. http://www.euromedsurgical.com
16. http://www.dyna-mesh.com
17. http://www.firamed.com
18. http://www.gissrl.com
19. http://www.gfe-medical.com
20. http://www.goremedical.com
21. http://www.herniamesh.com
22. http://www.klasmedical.com
23. http://www.microval.fr
24. http://www.2mdinc.com
25. http://www.mastbio.com
26. http://www.proxybiomedical.com
27. http://www.serag-wiessner.de
28. http://www.eindiabusiness.com/specialised-surgicalmesh/index.html
29. http://www.sukol.us
30. http://www.surgical-ioc.com
31. http://www.suturesin.com
32. http://www.taisiermed.com
33. http://www.texhitec.com
34. http://www.temedical.com
35. http://www.tyrx.com
36. http://www.xmed.it
37. http://www.worldofmedical.com

Table 3 List of manufacturers contacted directly by e-mail and relevant outcome

Manufacturer	Outcome
Abiss	Answer to provide the requested information
Adria	No answer
Angiologica	Answer to provide the requested information
Assut Europe	Answer to provide the requested information
Bard	Answer to provide the requested information
Corybros	No answer
Cousin	Answer to provide the requested information
Covidien	No answer
Euromed	No answer
Fira Medicale	Answer to provide the requested information
Klas Medical	Answer without providing the requested information
Proxy Biomedical	No answer
Specialised Surgical Mesh	No answer
Sukol	Answer to provide the requested information
Surgical Ioc	Answer to provide the requested information
Sutures India PL	No answer
Taisier-*Med*	Answer to provide the requested information
Transeasy Medical Tech	No answer
XMed	No answer

provided for the oldest prosthetics (Table 4). In these cases, we used the most recent values in our classification.

Among the 166 products, the following were excluded from the classification:

- Four prosthetics with memory rings and two with markers because their weights are altered by the additional materials
- Forty four prosthetics that were made of two or more different materials or made of different textures of the same material
- Twelve PET multifilament prosthetics
- One PET monofilament prosthetic
- Three Polytetrafluoroethylene (PTFE) monolayer prosthetics
- One Polyurethane (PU) prosthetic
- One Polyurethane (PU) prosthetic with drug
- One PGA prosthetic
- One PG910 prosthetic
- One PP monofilament prosthetic with drug
- One Polyethylene (PE) prosthetic
- One Polyethylene (PE) prosthetic with drug
- Ten non-woven prosthetics
- Three PP multifilament prosthetics

This left a homogeneous group of 80 PP, monofilament, knitted or woven, prosthetics that were further analyzed and categorized. Among the 80 prosthetics selected, the weight is available for 70 prosthetics (87%). As indicated above, in addition to weight (g/m^2), prosthetic thickness (mm) was also considered in the classification of the prosthetics. Yet, weight and thickness data were provided for just 40 prosthetics (50%).

Other pertinent data, such as yarn diameter, porosity and other physical properties of the prosthetics are equally important and could be the subject of further classification, though they are rarely published and not always available from the manufacturers. In this contest, these data were not considered in providing a homogeneous classification of these prosthetics.

The abbreviations of the biomaterials used in prosthetics are as follows:

CMC	Carboxymethyl cellulose
HA	Hyaluronic acid
O3FA	Omega-3 fatty acid
ORC	Oxidized cellulose regenerated
PDO	Polydioxanone
PE	Polyethylene
PEG	Polyethylene glycol

Table 4 Weight discrepancies for some prosthetics from literature and web sites

Company	Product	Weight (g/m^2)	References
Atrium	PROLITE	85	[7] web site
		90.2	[8] paper
Ethicon	PROLENE	82.5	[16] paper; [14] web site
		90	[17] paper
		100	[18, 19, 24] papers
		109	[21] paper
	ULTRAPRO	30 (only the PP portion)	[14] web site; [24] paper
		28 (only the PP portion)	[13, 14, 16, 22] papers
	VYPRO	30 (only the PP portion)	[26] paper
		26.8 (only the PP portion)	[8] paper
		25-27 (only the PP portion)	[16] paper

Table 5 Weight of polypropylene (PP) monofilament prosthetics

Company, Product	Weight (g/m^2)	Class
Herniamesh, HERMESH 7	19	Ultra-light
Mpathy-Mast, HERNIA MESH-MINIMESH	19	
Ami, HEXAPRO MESH	21	
Aspide, SURGIMESH XLIGHT	27.5	
Textile Hi-Tec, PARP PH	28	
Surgical Ioc, PROMESH LIGHT	28	
Herniamesh, HERMESH 8	30	
Cousin, BIOMESH P8	32	
B. Braun, OPTILENE MESH LP	36	Light
FEG-Textiltechnik, DYNAMESH-PP LIGHT	36	
Cousin, BIOMESH P9	38	
Covidien, PARIETENE LIGHT	38	
TransEasy Medical Tech, LMA	40	
Bard, SOFT MESH	44	
Ethicon, PROLENE SOFT	45	
Textile Hi-Tec, PARP PH2	45	
B. Braun, OPTILENE MESH ELASTIC	48	
Herniamesh, HERMESH 6	48	
DI.PRO, EVOLUTION	50	
Atrium, PROLITE ULTRA	50	
Abiss, CRISTALENE MID	54	
Klas Medikal, SUPROMESH LIGHT	55	
Sukol, DURAMESH MACROPORE	55	
Assut Europe, ASSUMESH LOW DENSITY	55	
Angiologica, ANGIMESH 0	56	
Taisier-Med, EGYMESH 1	56	
B. Braun, OPTILENE MESH	60	
TransEasy Medical Tech, PMM	60	
Microval, 2D KNITTED LW	64	
Abiss, CRISTALENE	70	Standard
FEG-Textiltechnik, DYNAMESH-PP STANDARD	72	
Covidien, PARIETENE	75	
Textile Hi-Tec, PARP PX	80	
TransEasy Medical Tech, PMP	80	
B. Braun, PREMILENE	82	
Ethicon, PROLENE	82.5	
Aspide, SURGIMESH 1	85	
Atrium, PROLITE	85	
Sukol, DURAMESH REGULAR THIN	85	
Herniamesh, HERTRA 9	88	
Bard, BARD MESH	90	
Assut Europe, ASSUMESH STANDARD	90	
Microval, 2D KNITTED STANDARD	91	
Euromed, EUROMESH	91	
Surgical Ioc, PROMESH T	97	
Cousin, BIOMESH P1	100	
Abiss, PERLENE	100	
Herniamesh, HERMESH 5	107	
Angiologica, ANGIMESH 1	107	
Herniamesh, HERMESH 4	112	
FiraMedicale, FIRAMESH STANDARD	115	
Sukol, DURAMESH REGULAR THICK	120	
Cousin, BIOMESH P3	125	
FiraMedicale, FIRAMESH MACROPOROUS	125	
Gis, RM1	127	
Herniamesh, HERMESH 3	127	
Angiologica, ANGIMESH 9	127	
Taisier-Med, EGYMESH 2	127	
Serag Wiessner, SERAMESH SO	130	
Aspide, SURGIMESH 2	130	
FiraMedicale, FIRAMESH SEMI-RIGID	175	Heavy
Herniamesh, HERTRA 2	177	
Gis, RM2	180	
Gis, RM3	220	
FiraMedicale, FIRAMESH RIGID	220	
Herniamesh, HERTRA 1	223	
Angiologica, ANGIMESH 8	223	
Gis, RM2	230	
Herniamesh, HERTRA 0	242	
Gis, RM3	250	

PET	Polyester (polyethylene terephthalate)
PEU	Polyether urethane
PG 910	Polyglactin 910
PGACL	Polyglycolic acid-caprolactone
PGCA	Polyglecaprone acid
PLA	Polylactic acid
PGA	Polyglycolic acid
PP	Polypropylene
cPP	Condensed polypropylene
PTFE	Polytetrafluoroethylene
cPTFE	Condensed polytetrafluoroethylene
ePTFE	Expanded polytetrafluoroethylene
PVDF	Polyvinylidene fluoride
PVP	Polyvinylpyrrolidone
PU	Polyurethane

Results

The analysis of the products available on the market suggested classification of prosthetics based on weight. Thus, the prosthetics are divided in four classes:

1. Ultra-light <35 g/m^2
2. Light ≥35 < 70 g/m^2
3. Standard ≥70 < 140 g/m^2
4. Heavy ≥140 g/m^2

Table 5 shows the weights of the 70 prosthetics and the classes to which they belong. The distribution of the prosthetics with regard to the above mentioned classification is represented in the histogram in Fig. 1.

Table 6 lists the 40 products for which both weight and thickness data are available.

We propose the following classification of the prosthetics based on the biomaterial with which they are manufactured:

1. *Simple* Prosthetics made of one pure biomaterial (PP, PET, PTFE, PGA or PU) with the same texture on both sides, mono- or multifilament, with or without drugs included.
2. *Composite* Prosthetics made of two or more different layers, one of which is simple (see point 1) while the other(s) are non-resorbable (A) or resorbable (B):

   (A) Non-resorbable layer/s (with or without drugs) include e-PTFE, PU, PEU, silicone, and condensed PP

   (B) Resorbable layer/s include collagen, collagen + PEG + glycerol, PDO + ORC, CMC + HA, PVP + PEG, O3FA.

3. *Combined* Two materials knitted or woven together.

   (A) Both materials non-resorbable:

   - Coated filaments (for example, PP with titanium)
   - Two filaments knitted or woven together (for example, PP + PVDF)

   (B) Only one filament resorbable:

   - PP monofilament + PGCA
   - PP monofilament + PLA
   - PP multifilament + PG 910
   - PET monofilament + PLA
   - PP monofilament + PGACL

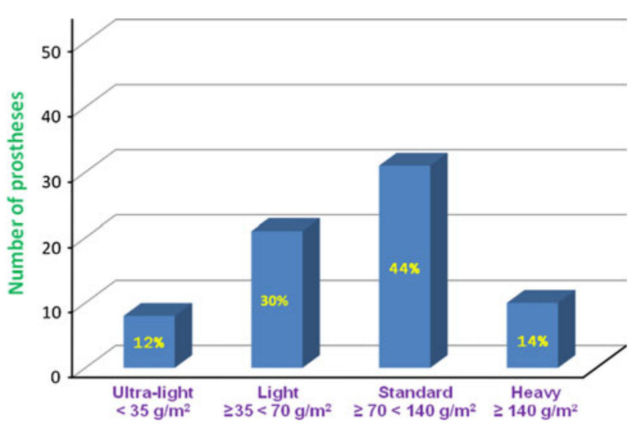

Fig. 1 Distribution of prosthetics based on weight classification

4. *Biological*

Table 7 shows a list of all 166 products, their classifications, and their related codes. Products with memory rings and markers are listed in the table, but not classified.

Discussion

It is interesting that prosthetic weight is not considered by Bendavid [7], in his book dedicated to chemical, physical and structural properties of synthetic biomaterials used in hernia repair. This meticulous text describes many properties of prosthetics, but not the weight. It is possible that this feature has become more important in recent years, when many new textiles have become available on the market.

In the past, Cobb [29] performed a complex experimental study on different prosthetics, categorizing them into heavy-weight (HW; 95 g/m^2), middle weight (MW; 45 g/m^2), and light weight (LW; 28 g/m^2) prosthetics, but the goal was only to distinguish the three prosthetics used in his study.

The reason why it is necessary to standardize a system of categorization of the prosthetics arises from the arbitrary language, not based on universal criteria, used by most of companies to define their products. Some examples are listed here: “ultra-light weight” or “extra-light weight”; “light-weight” or “low-weight” or “universal light prosthetic” or “thin prosthetic”; “mid-weight” or “standard weight” or “intermediate weight”, etc.

Recently, in 2008, another classification was proposed by Earle and Mark [30] as follows:

Ultra-light weight: <35 g/m^2
Light weight: 35–50 g/m^2
Medium weight: 51–90 g/m^2
Heavy-weight: >90 g/m^2

The authors classified prosthetics >90 g/m^2 as heavy-weight based on the severity of the host response. In our opinion, some class borders proposed here need to be modified. In fact, if we looked at Table 5 using Earle-Mark classification, prosthetics of 91 g/m^2 would belong to the same class of prosthetics of 250 g/m^2 (almost three times as heavy), despite the striking physical difference between them.

We suggest a classification, as reported in the “Results”, by starting from the upper limit of the ultra-light class proposed by Earle and Mark of 35 g/m^2, and doubling the

Table 6 List of weight (g/m^2) and thickness (mm) of prosthetics

Company	Product	Weight (g/m^2)	Thickness (mm)
HERNIAMESH	HERMESH 7	19	0.27
AMI	HEXAPRO MESH	21	0.38
TEXTILE HI-TEC	PARP PH	28	0.30
HERNIAMESH	HERMESH 8	30	0.32
COUSIN	BIOMESH P8	32	0.32
FEG TEXTILTECHNIK	DYNAMESH PP LIGHT	36	0.60
B. BRAUN	OPTILENE MESH LP	36	0.39
TRANSEASY MEDICAL TECH	LMA	40	0.50
TEXTILE HI-TEC	PARP PH2	45	0.40
B. BRAUN	OPTILENE MESH ELASTIC	48	0.55
HERNIAMESH	HERMESH 6	48	0.58
KLAS MEDICAL	SUPROMESH LIGHT	55	0.35
SUKOL	DURAMESH MACROPORE	55	0.71
ASSUT EUROPE	ASSUMESH LOW DENSITY	55	0.15
B. BRAUN	OPTILENE MESH	60	0.53
TRANSEASY MEDICAL	PMM	60	0.55
MICROVAL	2D KNITTED LW	64	0.45
FEG TEXTILTECHNIK	DYNAMESH PP STANDARD	72	0.70
TEXTILE HI-TEC	PARP PX	80	0.50
TRANSEASY MEDICAL TECH	PMP	80	0.52
B. BRAUN	PREMILENE	82	0.48
ETHICON J & J	PROLENE	82.5	0.60
SUKOL	DURAMESH REGULAR THIN	85	0.45
HERNIAMESH	HERTRA 9	88	0.53
ASSUT EUROPE	ASSUMESH STANDARD	90	0.50
EUROMED	EUROMESH	91	0.60
MICROVAL	2D KNITTED ST.	91	0.60
HERNIAMESH	HERMESH 5	107	0.49
COUSIN	BIOMESH P1	100	0.60
HERNIAMESH	HERMESH 4	112	0.53
FIRA MEDICALE	FIRAMESH STANDARD	115	0.60
SUKOL	DURAMESH REGULAR THICK	120	0.59
COUSIN	BIOMESH P3	125	0.60
FIRA MEDICALE	FIRAMESH MACROPOROUS	125	0.65
HERNIAMESH	HERMESH 3	127	0.54
FIRA MEDICALE	FIRAMESH SEMI-RIGID	175	0.75
HERNIAMESH	HERTRA 2	177	0.70
FIRA MEDICALE	FIRAMESH RIGID	220	0.85
HERNIAMESH	HERTRA 1	223	0.83
HERNIAMESH	HERTRA 0	242	0.73

next limits for each class, following a progressive trend (35–70–140). These class limits give a better distribution of prosthetics, and avoid the marked break between third and fourth class at 90 g/m^2. On the other hand, the principle of host response is not the sole criteria for classifying prosthetics. Moreover, data on host responses are not incontrovertible for all prosthetics.

As expected, and in support of our proposal for classification, the greatest number of prosthetics (44%), belongs to the “standard” class, as shown in the bar graph in Fig. 1. In fact, although ultra-light and light devices have been launched in recent years, standard meshes have unarguably made history in hernia surgery, thus it is reasonable that they belong to the most numerous class. The lowest

Table 7 Companies, products and biomaterials with classification codes

Company (website)[a]	Product	Biomaterial	Class code
ABISS (1)	CRISTALENE MID	PP MONOFIL	1
	CRISTALENE	PP MONOFIL	1
	PERLENE	PP MONOFIL	1
ADRIA (2)	ADRIMESH	PP MONOFIL	1
AMI (3)	HEXAPRO MESH	PP MONOFIL	1
ANGIOLOGICA (4)	ANGIMESH 0	PP MONOFIL	1
	ANGIMESH 1	PP MONOFIL	1
	ANGIMESH 8	PP MONOFIL	1
	ANGIMESH 9	PP MONOFIL	1
	ANGIMESH R2	PET MULTIFIL	1
	COMBIMESH PLUS	PP MONOFIL + PU	2A
ASPIDE (5)	SURGIMESH XLIGHT	PP MONOFIL	1
	SURGIMESH 1	PP MONOFIL	1
	SURGIMESH 2	PP MONOFIL	1
	SURGIMESH WN	NW PP	1
	SURGIMESH PET 2D	PET MULTIFIL	1
	SURGIMESH PET 3D	PET MULTIFIL	1
	SURGIMESH XB	NW PP + SILICONE	2A
ASSUT EUROPE (6)	ASSUMESH STANDARD	PP MONOFIL	1
	ASSUMESH LOW DENSITY	PP MONOFIL	1
ATRIUM (7)	PROLITE ULTRA	PP MONOFIL	1
	PROLITE	PP MONOFIL	1
	C-QURE MESH	PP MONOFIL + O3FA	2B
BARD (8)	BARD SOFT MESH	PP MONOFIL	1
	BARD MESH	PP MONOFIL	1
	SEPRAMESH IP COMPOSITE	PP MONOFIL + hydrogel coating	2B
	VISILEX	PP MONOFIL	1
	DULEX	PTFE + PTFE	2A
	COMPOSIX E/X	PP MONOFIL + PTFE	2A
	COMPOSIX L/P	PP MONOFIL + PTFE	2A
B. BRAUN (9)	OPTILENE MESH LP	PP MONOFIL	1
	OPTILENE MESH ELASTIC	PP MONOFIL	1
	OPTILENE MESH	PP MONOFIL	1
	PREMILENE	PP MONOFIL	1
	OMYRA MESH	cPTFE	1
	SAFIL MESH	PGA	1
CORYBROS (10)	SURGICAL MESH ULTRALIGHT	PP MONOFIL	1
	SURGICAL MESH LIGHT	PP MONOFIL	1
	SURGICAL MESH REGULAR	PP MONOFIL	1
	SURGICAL MESH DENSE	PP MONOFIL	1
	COMBINATION MESH	PP + PU	2A
COUSIN (11)	BIOMESH P1	PP MONOFIL	1
	BIOMESH P3	PP MONOFIL	1
	BIOMESH P8	PP MONOFIL	1
	BIOMESH P9	PP MONOFIL	1
	BIOMESH A2	PET MULTIFIL + SILICONE	2A
	INTRAMESH W3	PET NW + SILICONE	2A
	INTRAMESH T1	PP MONOFIL + e-PTFE	2A
	ADHESIX	PP MONOFIL + PVP + PEG	2B
	BIOMESH SR	PP MONOFIL + PLA	3B

Table 7 continued

Company (website)[a]	Product	Biomaterial	Class code
COVIDIEN (12)	PARIETENE LIGHT	PP MONOFIL	1
	PARIETENE	PP MONOFIL	1
	PARIETENE PRO-GRIP	PP MONOFIL + PLA	3B
	PARIETEX LIGHTWEIGHT	PET MONOFIL	1
	SURGIPRO	PP MONOFIL	1
	SURGIPRO	PP MULTIFIL	1
	PARIETENE COMPOSITE	PP MONOFIL + collagen/PEG/glycerol	2B
	PARIETEX PRO-GRIP	PET MONOFIL + PLA	3B
	PARIETEX COMPOSITE	PET + collagen/PEG/glycerol	2B
	PARIETEX FLAT SHEET 2D	PET MULTIFIL	1
	PARIETEX FLAT SHEET 3D	PET MULTIFIL	1
DIPRO MED (13)	CLEAR MESH COMPOSITE	PP MONOFIL + cPP	2A
	EVOLUTION	PP MONOFIL	1
	MEDIUM WEIGHT MESH	PP MONOFIL	1
	HEAVY WEIGHT MESH	PP MONOFIL	1
ETHICON (14)	PROLENE SOFT	PP MONOFIL	1
	PROLENE	PP MONOFIL	1
	ULTRAPRO	PP MONOFIL + PGCA	3B
	VICRYL	PG 910	1
	MERSILENE	PET MULTIFIL	1
	PROCEED	PP + PDO + ORC	2B
	PHYSIOMESH	PP + PGCA + PDO	2B
EUROMED (15)	EUROMESH	PP MONOFIL	1
FEG TEXTILTECHNIK (16)	DYNAMESH PP LIGHT	PP MONOFIL	1
	DYNAMESH PP STANDARD	PP MONOFIL	1
	DYNAMESH-IPOM	PVDF + PP	3A
FIRA MEDICALE (17)	FIRAMESH STANDARD	PP MONOFIL	1
	FIRAMESH MACROPOROSA	PP MONOFIL	1
	FIRAMESH SEMI-RIGIDA	PP MONOFIL	1
	FIRAMESH RIGIDA	PP MONOFIL	1
GIS (18)	RM1	PP MONOFIL	1
	RM2 (×2)	PP MONOFIL	1
	RM3(×2)	PP MONOFIL	1
	RM (RRS)	PP MONOFIL + silicon marker	–
	RM (RRT)	PP MONOFIL + titanium marker	–
GFE (PFM) (19)	TiMESH	PP MONOFIL + Ti coating	3A
	TiMESH LT	PP MONOFIL + Ti coating	3A
	TiMESH XLT	PP MONOFIL + Ti coating	3A
GORE (20)	INFINIT MESH	PTFE MONOFIL	1
	DUALMESH	e-PTFE with 2 layers	2A
	DUALMESH PLUS	e-PTFE with 2 layers + antibiotics	2A
	MICROMESH	e-PTFE with 2 layers	2A
	MICROMESH PLUS	e-PTFE with 2 layers + antibiotics	2A
HERNIAMESH (21)	HERMESH 7	PP MONOFIL	1
	HERMESH 8	PP MONOFIL	1
	HERMESH 6	PP MONOFIL	1
	HERMESH 5	PP MONOFIL	1
	HERMESH 4	PP MONOFIL	1
	HERMESH 3	PP MONOFIL	1
	HERTRA 9	PP MONOFIL	1

Table 7 continued

Company (website)[a]	Product	Biomaterial	Class code
	HERTRA 2	PP MONOFIL	1
	HERTRA 1	PP MONOFIL	1
	HERTRA 0	PP MONOFIL	1
	RELIMESH	PP MONOFIL + e-PTFE	2A
KLAS MEDICAL (22)	SUPROMESH LIGHT	PP MONOFIL	1
	SUPRO DRAPE	PE	1
	SUPRO DRAPE	PU	1
	SUPRODRAPE HI-TEC	PE + antibiotics	1
	SUPRO DRAPE HI-TEC	PU + antibiotics	1
MICROVAL (23)	2D NON WOVEN	NW PP	1
	2D KNITTED STANDARD	PP MONOFIL	1
	2D KNITTED LW	PP MONOFIL	1
	2D KNITTED POLYESTER	PET MULTIFIL	1
	INTRA IMPLANT	NW PP + silicon	2A
MMDI (24)	REBOUND HRD hybrid small	cPP + Ni–Ti cable frame	–
	REBOUND HRD butterfly	cPP + Ni–Ti cable frame	–
	REBOUND HRD dog bone	cPP + Ni–Ti cable frame	–
	REBOUND HRD V ventral	cPTFE + Ni–Ti cable frame	–
MPATHY/MAST (25)	HERNIA MESH/MINIMESH	PP MONOFIL	1
PROXY BIOMEDICAL	VITAMESH	PP MONOFIL	1
(26)	MOTIFMESH	cPTFE	1
SERAG WIESSNER (27)	SERAMESH SO	PP MONOFIL	1
	SERAMESH SE	PP MULTIFIL	1
	SERAMESH LE	PP MULTIFIL	1
	SERAMESH PA	PP MONOFIL + PGACL	3B
SPECIALISED SURGICAL MESH (28)	SURGIEMESH	PP MONOFIL	1
SUKOL (29)	DURAMESH REGULAR THICK	PP MONOFIL	1
	DURAMESH REGULAR THIN	PP MONOFIL	1
	DURAMESH MACROPORE	PP MONOFIL	1
SURGICAL IOC (30)	PROMESH T	PP MONOFIL	1
	PROMESH NT	NW PP	1
	PROMESH LIGHT	PP MONOFIL	1
	HERNIA TEX A1C	PET MULTIFIL + collagen	2B
	HERNIA TEX 3DC	PET MULTIFIL + collagen	2B
	PROMESH SOFT	PET MULTIFIL(3D)	1
	PROMESH FLEX	PET MULTIFIL(2D)	1
	SIL PROMESH	NW PP-SILICONE	2A
SUTURES INDIA PL (31)	TRULENE	PP MONOFIL	1
TAISIER-MED (32)	EGYMESH 1	PP MONOFIL	1
	EGYMIX	PP MONOFIL + PGACL	3B
TEXTILE HI-TEC (THT)-Montpellier (33)	PARP PH	PP MONOFIL	1
	PARP PH2	PP MONOFIL	1
	PARP PX	PP MONOFIL	1
	PARP 1P	NW PP	1
	PARP 8P	NW PP	1
	PARP 9P	NW PP	1
	PARP 3D	PET MULTIFIL	1
	FARP 2D	PET MULTIFIL	1

Table 7 continued

Company (website)[a]	Product	Biomaterial	Class code
	PARL 4D	PET MULTIFIL	1
	FARP 2+	PET MULTIFIL + PEU	2A
	CONT 3+	PET MULTIFIL + PEU with grips	2A
	IRPC 2D	PET MULTIFIL + collagen	2B
	IRPC 3D	PET MULTIFIL + collagen	2B
	ENDO IP	PET MULTIFIL + PEU	2A
	PARP MP	PET MULTIFIL + PEU	2A
	PARP MP3	PET MULTIFIL + PEU	2A
TRANSEASY MEDICAL TECH (34)	PMM	PP MONOFIL	1
	PMP	PP MONOFIL	1
	LMA	PP MONOFIL	1
TYRX (35)	PIVIT AB	PP MONOFIL + drugs	1
XMED (36)	MEDMESH	PP MONOFIL	1
WORLDOFMEDICAL (WOM) (37)	W 50 EV	NW PP + SILICONE	2A
	W 50	NW PP	1
	W 70	NW PP	1
	W70C	NW PP	1
	W 90	NW PP	1

[a] Websites listed are numbered in Table 2

number of prosthetics (12%) belonged to the "ultra-light" class, although this is comparable to the number of prosthetics in the "heavy" class (14%).

Figure 2 shows the distribution of the prosthetics according to the previous Earle-Mark classification. In this case, the distribution appears as an increasing trend with the greatest number of prosthetics (40%) belonging to the "heavy" class, which is less rational.

The classification of prosthetics based on weight only regards PP monofilament knitted or woven prosthetics as belonging to the "Simple" class in our biomaterial-based classification.

The use of this classification can also be suggested for biomaterials of the "Combined" class, but, in this case, it is important to indicate the weight of the non-resorbable part of the prosthetic to have comparable values.

Unfortunately, companies do not often report or disclose their prosthetic data. The weights are known for only 70/80 (87%) and the thickness for just 40/80 (50%) prosthetics.

If we consider the prosthetics for which both weight and thickness are known (Table 6), 5 are classified as ultra-light prosthetics (about 12%), 12 as light prosthetics (30%), 18 as standard prosthetics (45%), and 5 as heavy prosthetics (about 12%).

Conclusions

Aristotle, the ancient Greek philosopher, stressed the paramount importance of achieving a common language for a better understanding among individuals within a society. Along these lines, science requires the proper use of technical vocabulary. It is an absolute necessity that scientists and clinicians, while coming from different backgrounds and educational systems, agree upon and utilize a common language based on mutually understood concepts and definitions [31].

To this end, a new prosthetic classification is proposed that considers both the weight of the prosthetic and the biomaterial used to manufacture it.

The weight classification has been suggested after extensive analysis of the products available on the market. Considering that most prosthetics are made of PP monofilament, the classification is focused particularly on this biomaterial.

At the same time, a classification of the prosthetic based on biomaterial alone is proposed.

It is clear that this work is part of a more complex job that should be performed to define a common language for both companies and surgeons. We strongly suggest that a working group be created, to include both technicians and physicians, whose aims are to:

- define the most important properties for characterizing prosthetics for surgical applications. Possible properties may include weight, thickness, tensile strength, burst strength, tear strength, elasticity, suture retention, pore size, percentage porosity, and yarn diameter.
- define standardized testing methods that will be used for each of the above mentioned properties.

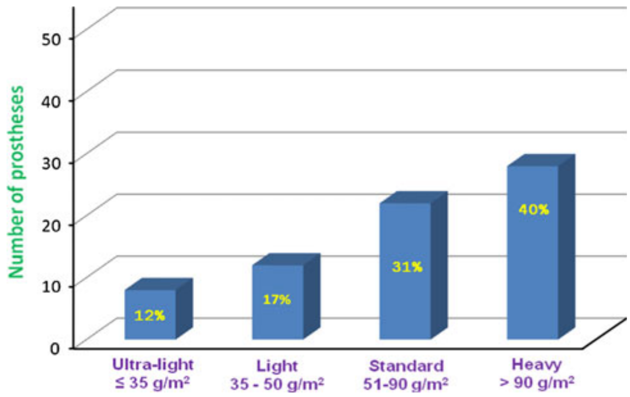

Fig. 2 Distribution of prosthetics following the Earle and Mark [30] weight classification

- define which of the above-mentioned data must be published by the manufacturers of the prosthetics.

Acknowledgments This paper concerning the classification of prosthetics used in hernia repair has been developed with the co-operation with Herniamesh Srl, [Via Fratelli Meliga 1/C, Chivasso (TO), Italy].

Declaration The authors apologize in advance for any imprecision, oversight or omission about products and companies and kindly request that companies contact them with any suggestions or comments that will further improve upon the database. A.C. declares that he received no grant support for this work.

References

1. Melick DW (1942) Nylon sutures. Ann Surg 115:475–476
2. Aquaviva D, Bounet P (1944) Cure d'une volumineuse eventration par plaque de Crinofil. Extraits Bull Soc Chir de Marseille 1944. quoted by Zagdoun J–Sordinas A, L'utilisation des plaques de nylon dans la chirurgie des hernies inguinales, Academie de Chirurgie, Sèance du 25 Nov 1959, 747–54
3. Maloney GE, Gill WG, Barclay RC (1948) Operations for hernia: technique of nylon darn. Lancet 2:45–48
4. Usher FC, Wallace SA (1958) Tissue reaction to plastic: comparison of Nylon, Orlon, Teflon and Dacron. Arch Surg 76:997–999
5. Usher FC, Ochsner J, Tuttle LLD (1959) Marlex mesh: a new plastic mesh for replacing tissue defects, experimental studies. Am Surg 24(12):969–974
6. Usher FC (1961) Knitted Marlex mesh. An improved Marlex prosthesis for repairing hernias and other tissue defects. Arch Surg 82:771–773
7. King MW, Soares BM, Guidoin R (1994) The chemical, physical and structural properties of synthetic biomaterials used in hernia repair. In: Bendavid R (ed) Prostheses and abdominal wall hernias. Landes, Austin, pp 191–206
8. Klinge U, Klosterhalfen B, Schumpelick V (2001) Vypro®: a new generation of Polypropylene Mesh. In: Bendavid R et al (eds) Abdominal wall hernias: principles and management. Springer, New York, pp 286–291
9. Udwadia TE (2007) Commercial mesh versus nylon mosquito net for hernia repair. A randomized double-blind study in Burkina Faso. World J Surg 31(4):858. [http://www.ncbi.nlm.nih.gov/pubmed/16983472]
10. Wilhelm TJ (2007) Sterilized mosquito net versus commercial mesh for hernia repair. an experimental study in goats in Mbarara/Uganda. Eur Surg Res 39(5):312–317. [http://www.ncbi.nlm.nih.gov/pubmed/17595545]
11. Clarke MG (2009) The use of sterilised polyester mosquito net mesh for inguinal hernia repair in Ghana. Hernia 13(2):155–159. doi:10.1007/s10029-008-0460-3. [http://www.springerlink.com/content/u147um764l3j4227/]
12. Schumpelick V, Klinge U, Rosch R, Junge K (2006) Light weight meshes in incisional hernia repair. J Min Access Surg 2(3):117–123
13. Klingensmith ME, Chen LE, Glasgow SC, Goers TA (eds) (2007) Hernias. In: The Washington manual of surgery. Lippincott Williams & Wilkins, Philadelphia, pp 442–452
14. The significance of a mesh thickness in the operation of inguinal hernia (2007–2009) [http://clinicaltrials.gov/ct2/show/NCT00451893]
15. ftp://ftp.polito.it/people/cesal/Polimeri_Medicina/Trombetta.pdf
16. Klosterhalfen B, Junge K, Klinge U (2005) The lightweight and large porous mesh concept for hernia repair. Expert Rev Med Devices 2(1):103–117
17. Kraft B (2006) Meshes and mesh-fixation techniques in TAPP hernia-repair. Surg Laparosc Endosc Percutan Tech 16(6):448–449
18. Horstmann R (2006) Impact of polypropylene amount on functional outcome and quality of life after inguinal hernia repair by the TAPP procedure using pure, mixed, and titanium-coated meshes. World J Surg 30:1–8
19. Lauscher JC (2008) Total extraperitoneal hernioplasty: does the long-term clinical course depend on the type of mesh? J Laparoendosc Adv Surg Tech 18:6–9
20. Karsten J (2002) Functional and morphologic properties of a modified mesh for inguinal hernia repair. World J Surg 26(12):1472–1480
21. Schmidbauer S, Ladurner R, Hallfeldt KK, Mussack T (2005) Heavy-weight versus low-weight polypropylene meshes for open sublay mesh repair of incisional hernia. Eur J Med Res 10:247–253
22. Schug-Paß C, Tamme C, Sommerer F, Tannapfel A, Lippert H, Köckerling F (2008) A lightweight, partially absorbable mesh (Ultrapro) for endoscopic hernia repair: experimental biocompatibility results obtained with a porcine model. Surg Endosc 22:1100–1106
23. Holzheimer RG (2004) First results of Lichtenstein hernia repair with Ultrapro-mesh as cost saving procedure—quality control combined with a modified quality of life questionnaire (SF-36) in a series of ambulatory operated patients. Eur J Med Res 9(6):323–327
24. Khan LR, Liong S, de Beaux AC, Kumar S, Nixon SJ (2010) Lightweight mesh improves functional outcome in laparoscopic totally extra-peritoneal inguinal hernia repair. Hernia 14:39–45
25. Smietański M, Bigda J, Zaborowski K, Worek M, Sledziński Z (2009) Three-year follow-up of modified Lichtenstein inguinal hernioplasty using lightweight poliglecaprone/polypropylene mesh. Hernia 13:239–242
26. Zieren J, Neuss H, Ablassmaier B, Müller JM (2002) Adhesions after intraperitoneal mesh repair in pigs: Prolene™ vs. Vypro™. J Laparoendosc Adv Surg Tech A 12(4):249–252
27. Tamme C, Garde N, Klingler A, Hampe C, Wunder R, Köckerling F (2005) Totally extraperitoneal inguinal hernioplasty with titanium-coated lightweight polypropylene mesh: early results. Surg Endosc 19(8):1125–1129

28. Anderson JR (2006) Ultralightweight Polypropylene mesh for abdominal wall hernia repair. Annual Conference of the British Hernia Society, Abstract Book, British Hernia Society, Nottingham
29. Cobb WS et al (2006) Textile analysis of heavy weight, mid-weight, and light weight polypropylene mesh in a porcine ventral hernia model. J Surg Res 136(1):1–7
30. Earle DB, Mark LA (2008) Prosthetic material in inguinal hernia repair: how do I choose? Surg Cl N Am 88:179–201
31. Cobb WS, Peindl RM, Zerey M, Carbonell AM, Heniford BT (2009) Mesh terminology 101. Hernia 13:1–6