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Review article

A proposal for the study of cementless short-stem hip prostheses

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ABSTRACT. ***Background:*** **With the recent evolution of hip arthroplasty, new models of short stems have emerged. So far, we do not have a clear strategy to analyze their outcomes, since there is confusion around the definition of short stem and there is no consensus for their classification.** ***Purposes:*** **The purpose of this study was to review the current state of the art of cementless short stems considering the main design characteristics; it provides a definition of short stem and proposes a classification, grouping them into families by means of a nomenclature that describes them accurately.** ***Material and methods:*** **We conducted a search in the PubMed and Scopus databases and consulted various implant manufacturers, foundations devoted to research on joint arthroplasty, organizations of independent experts on medical device analysis, and national arthroplasty registries. The stems studied were classified according to a new nomenclature system.** ***Conclusions:*** **We identified 44 different models that share 84 design variables and may be grouped into three types and 16 generic families. The stems were manufactured by 20 different companies. Short stems are those occupying the neck, metaphysis and the proximal aspect of the limit between the metaphysis and diaphysis, regardless of the geometric type of endosteum present. A wide variety of models was identified, with multiple**

RESUMEN: ***Antecedentes:*** **Con la reciente evolución de la artroplastia de cadera han surgido nuevos modelos con componentes femorales cortos. Aún no se tiene una forma clara de analizar sus resultados pues existe confusión en las definiciones y no tenemos una clasificación universal.** ***Objetivos:*** **Revisar el estado del arte de los componentes femorales cortos no cementados, considerar sus características de diseño, tratar de establecer una clasificación y una nomenclatura que permita una mejor definición del implante.** ***Material y métodos:*** **Realizamos una búsqueda en PubMed y Scopus, consultamos a varios fabricantes, fundaciones dedicadas a la investigación en artroplastías, organizaciones dedicadas al análisis de los implantes y algunos registros nacionales de artroplastías. Los componentes femorales estudiados se agruparon en esta clasificación propuesta.** ***Conclusiones:*** **Identificamos 3 tipos y 16 familias genéricas de implantes, se logró establecer una clasificación que generó una nueva nomenclatura que permite la identificación específica de cada uno de los diseños.**

Level of evidence: III

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design variables. In order to classify them, it was necessary to design a whole new nomenclature capable of describing them in an unequivocal, unique and distinctive way.

Key words: Arthroplasty, hip, replacement, short stem, classification, trends.

Key words: Artroplastía, cadera, vástago corto, clasificación, tendencia.

Introduction

Cementless fixation of femoral prosthetic components is the preferred procedure of many surgeons despite the fact that a certain percentage of the former may fail in the long term, resulting in events that alter periprosthetic bone turnover and changes that, at times, are unwanted. These changes have multifactorial causes and are mainly due to the elimination of trabecular systems that transmit mechanical stimuli and, therefore, lead to the devascularization of the proximal femoral endosteum. To the former we need to add the skeletal changes resulting from aging, the effects that certain comorbidities common in patients undergoing arthroplasty have on bone, and the use of certain medications that affect bone mineralization and metabolic turnover, with the resulting bone mass loss. New concepts in implant design have appeared as an attempt to diminish the above-mentioned changes; this is the purpose of short stems.

This relatively «new» design concept has a series of advantages. The most relevant ones include its bone-preserving features, the fact that it is less invasive and, since it is anchored mostly in the femoral head-metaphysis area, it may limit the defunctionalization of the proximal femoral bone. Other less important advantages have been described, some of which are questionable: 1) the possibility of minimizing or eliminating the difficulties that at times occur when trying to adapt a design to the anatomical geometric differences between the proximal and the distal femur; 2) some designs avoid the challenge of matching the medial implant geometry to the calcar femorale (Adam's arch); 3) they can be more easily fitted in cases of preexisting femoral bone deformities; 4) revision surgeries are easier; 5) they facilitate anterior approaches; 6) the theoretical improvement in proximal bone turnover reduces the chance of stress shielding or reactive bone changes; 7) less intraoperative bleeding is expected; 8) they require less instrumentation; 9) they help reduce inventory costs, and 10) they theoretically reduce the length of the postoperative rehabilitation period.[1,2,3,4,5,6] Despite the above arguments, these and other possible advantages are valid only if one can prove that they are better than those offered by standard stems from the standpoint of survival and revision rates, clinical outcomes, and the preservation of good bone health.

The questions we should ask before making the decision of prescribing new implants are: Are their indications clearly defined? Are their clinical results better? Do they provide better or, at least equal, stability than standard stems? Are they equally or more durable? Do the different designs available offer the same advantages? To answer these and other questions one needs a clear strategy that analyzes how the different currently available short-stem designs function and what their clinical outcomes are. But before this, we need to face two fundamental problems on which, so far, no consensus has been reached: 1) define what we mean by short stem, and 2) make a standardized classification helping us group stems and compare their results as well as perform multicenter comparative analyses without mixing, to the extent possible, the various design philosophies.

The word «short» may have various meanings depending on the context where it is used. For purposes of this paper, «short» is something having little length or size. Short stems may be referred to as short hip stems, shorter hip stems or shortened hip stems. It is a fact that there is no consensus as to what the dimensions of a short stem are. It is therefore very important to reach an agreement as to what we mean by short endoprosthetic femoral implants.

Several authors have proposed stem classifications using various criteria in order to analyze their clinical outcomes.[7,8,9,10,11] However, their drawback is that they mix various implant concepts, types and designs in such a way that they sometimes include even standard stems; this has led to confusion in the interpretation of results. For these and other reasons, we deem important to start a discussion that helps us better understand this type of stems.

In general, the design of short femoral implants is based on the following features: 1) anatomical region they occupy or invade, 2) basic geometric design, 3) main stress distribution zones, 4) bone resection level in the femoral head, neck or metaphysis, and 5) the orientation axes used for insertion. The purpose of this study was to review current cementless short stems considering the above-mentioned characteristics and propose a classification grouping them into families by means of a nomenclature that describes them accurately.

Material and methods

To collect data on current cementless short stems, we did an internet search in the PubMed and Scopus databases.

We also consulted with various implant manufacturers, joint arthroplasty research foundations, organizations of independent experts in analyzing medical devices, and national arthroplasty registries. We excluded cemented stems and animal prototypes from this analysis. This study did not analyze clinical outcomes.

Some of the stems included are still in use, while others are part of clinical research trials, were developed only as a prototype, or have been recalled from the market. But the common denominator in all of them is that they have been implanted in human patients.

The following criteria were used to classify the designs included here in: a) the anatomical region they occupy or invade *(Figures 1 and 2)*; b) the bone resection level *(Figure 3)*; c) the main stress transmission areas *(Figure 4)*; d) the relevant morphological and geometric design characteristics, and e) the orientation axes to introduce the implant in the femur depending on whether the stem is femoral neck sparing or not sparing.

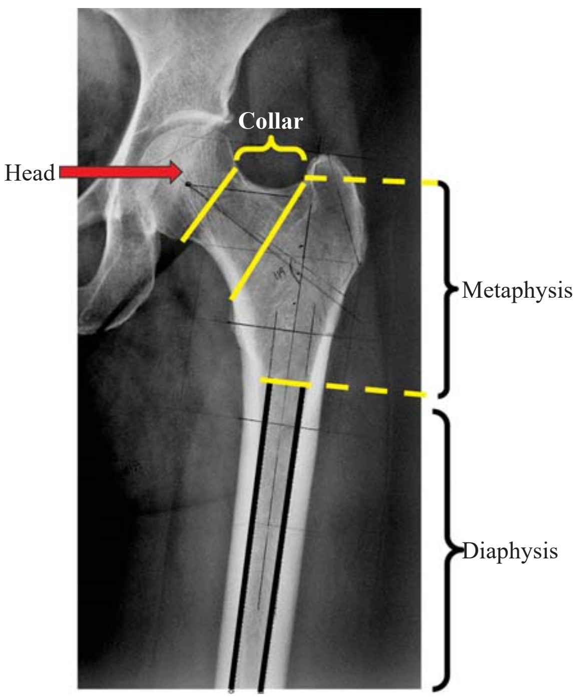

Figure 1. The proximal femur is divided into the head, collar, metaphysis and diaphysis regions.

To determine which areas occupied by the implants in the proximal femur and their major stress transmission areas we considered the manufacturers' descriptions, the imaging analyses of the plain films published in different media, and, finally, an intuitive rationale based on the morphological analysis and the characteristics of each design. The loading/stress transmission sites may be: a) part of the femoral head, b) all or part of the neck with or without a collar, c) on the calcar, d) on the metaphyseal cancellous bone, e) on both metaphyseal cortices, f) on the lateral metaphyseal/diaphyseal cortex and g) on the shaft. All of them experience loading on several sites at a time *(Figure 4)*, and their main morphological and design characteristics in order to define their anteroposterior, lateral and cross-sectional profiles; their overall, cross-sectional and lateral geometry, modularity, stem surface and type of primary anchoring *(Table 1)*.

Given the huge diversity of stem models considering the above described variables, a nomenclature was designed to name them. It describes each one of them in an easy, unequivocal, unique and distinctive way, and allows classifying and grouping them in families. Most stems share several variables, but more than one of them may be present in some of the models. *Table 2* describes the proposed nomenclature and its acronyms.

Results

We identified 42 different models manufactured by 20 companies, which may be grouped into 3 types and 16 generic families *(Table 3)*. Eighty-four design variables were identified in the stems analyzed *(Table 4)*. The 42 models share several design variables.

The proposed classification in *Table 5* only shows examples for each family to illustrate the methodology used for their identification, classification, and grouping. Annex "A" shows the full classification of all the stems identified in this paper (*The annex is online only*).

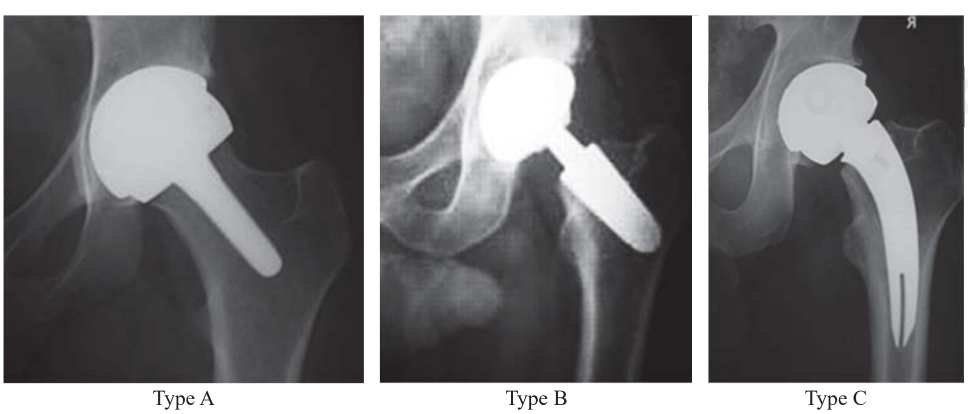

Figure 2.

Classification of short stems according to the regions they occupy or invade. **Type A)** It occupies the head-collar-metaphysis regions. (E.g., Birmingham Mid-Head Resection) **Type B)** It occupies the collar-metaphysis regions. (E.g., Silent short stem). **Type C)** It occupies the collar-metaphysis-diaphysis regions. (E.g., TSI™ Neck Sparing Stem).

Discussion

Current short stems offer potential theoretical advantages that may exceed those offered by conventional ones. However, the former are only valid if they prove to be better from the perspective of their clinical results, long-term survival, less complications, and fewer unwanted reactions resulting from periprosthetic bone turnover. Proving their superiority involves facing two outstanding problems among many others: a) their definition, and b) their classification.

Some authors have made attempts to define them using various criteria, however: a) there is no clear definition of the numeric length that a short stem should have, b) the variable proportions between certain landmarks makes it difficult to establish correlation indices, and c) the border separating the metaphysis and the shaft is quite imprecise. Due to the above, the definition of short stem should not consider only a universal numerical value[8] or the anatomical correlation indices.[7]

Regarding the possibility of adopting a universal numerical factor, Feyen et al.[7] reported the lengths of some stems considered as short. *Table 6* shows that the length range is quite broad, from 76 to 155 mm. Another attempt to name them considers their anatomical borders. Stulbergh[12] states that a short stem should be less than 120 mm long, as the metaphysis-diaphysis junction is located precisely at

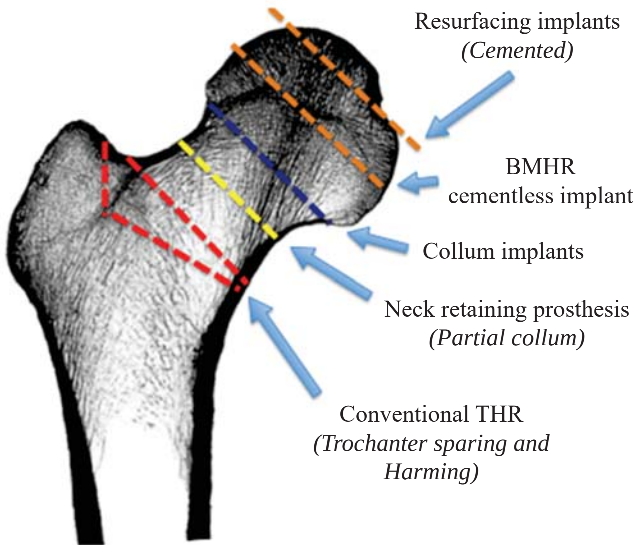

Figure 3. Short implants have various resection levels depending on their design philosophy, which include resurfacing implants, which are only cemented; Birmingham mid-head resection (BMHR), collum or collar implants, neck retaining implants, and standard short stems that may or may not invade the greater trochanter.

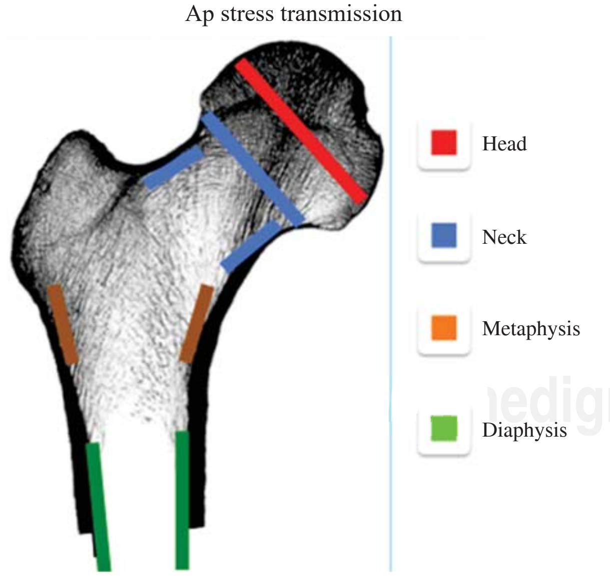

Figure 4. Load/stress transmission variables: 1) on the femoral head, 2) on all or part of the neck 3) on the calcar 4) on the metaphyseal cancellous layer, 5) on both metaphyseal cortices, 6) on the lateral metaphyseal-diaphyseal cortex, 7) on the diaphysis, and 8) some may have several simultaneous loading sites.

Table 1. Morphologic and design characteristics of short stems.

Anatomical region they occupy or invade A. Head, neck, and metaphysis B. Neck and metaphysis C. Neck, metaphysis, and diaphysis **Overall geometry** • Cylindrical • Prismatic • Wedge-shaped - Straight wedge - Curved wedge - Bidirectional wedge • Tapered - Straight tapered - Curved tapered - Bidirectional tapered • With beveled distal tip **Cross-sectional geometry** • Round • Oval • Oval-trapezoid • Rectangular-trapezoid • Polygonal **Lateral profile geometry** • Straight • Angled • Two-angled	**Major stress transmission areas** • Loading on part of the femoral head • Loading on part of the femoral neck - WC = With collar - WoC = Without collar • Loading on the metaphyseal cancellous bone • Loading on both metaphyseal cortices • Loading on the middle metaphyseal cortex (calcar) • Loading invades the trochanteric region • Loading on the lateral cortex • They cross the lateral metaphyseal cortex - Without extramedullary support - With extramedullary support • Loading on the proximal diaphysis • Loading in the diaphysis **Type of fixation** • Screwed • Press-fit **Modularity** • Modular • Monoblock **Stem surface** • Hydroxyapatite • Other calcium-phosphates • Different types of coated titanium alloys • Different types of coated cobalt-chrome alloys

Table 2. Nomenclature of short stems.

1) Based on the anatomical region they occupy or invade
- **A** = They occupy the head, neck, and metaphysis
- **B** = They occupy the neck (*with various resection levels*) and the metaphysis
- **C** = Part of the neck, metaphysis, and diaphysis

2) Based on their overall geometry
- **1** = Cylindrical overall geometry
- **2** = Prismatic overall geometry.
- **3** = Wedge-shaped overall geometry
  - **3.1** = Straight wedge
  - **3.2** = Curved wedge
  - **3.3** = Bidirectional wedge
- **4** = Tapered overall geometry
  - **4.1** = Straight tapered
  - **4.2** = Curved tapered
  - **4.3** = Bidirectional tapered
- **dB** = With distal tip bevel (*«diapason» tip*).

3) Based on their main geometric design characteristics (anteroposterior, lateral and cross-sectional planes)
- **CSG1** = Round cross-sectional geometry
- **CSG2** = Oval cross-sectional geometry
- **CSG2.1** = Oval-trapezoidal cross-sectional geometry
- **CSG3** = Rectangular cross-sectional geometry
- **CSG4** = Polygonal cross-sectional geometry

4) Based on their lateral geometry
- **SLP** = Straight lateral profile
- **ALP** = Angled lateral profile

5) Based on their major stress transmission areas
- **FH** = Loading on part of the femoral head
- **FN** = Loading on part of the femoral neck
  - WC = With collar
  - WoC = Without collar
- **CM.1** = Loading on the metaphyseal cancellous bone.
- **CM.2** = Loading on both metaphyseal cortices.
- **CM.3** = Loading on the middle metaphyseal cortex (calcar).
- **CM.4** = Also loading invades the trochanteric region.
- **CM.5** = Loading on the lateral cortex
- **CM.6** = Crossing the lateral metaphyseal cortex
  - WoES = Without extramedullary support
  - WES = With extramedullary support
- **PDL** = Loading on the proximal diaphysis
- **DL =** Loading in diaphysis

6) Based on their type of fixation
- **s** = Screwed
- **PF** = Press-fit

7) Based on their modularity
- **HMDS** = Head Modular stems
- **CMDS** = Collo Modular stems
- **MBS** = Monoblock stems

8) Stem surface
- **HA** = Hydroxyapatite-coated
- **CP** = Calcium-phosphate coated
- **Ti** = Different types of titanium-coated
- **CoCr** = Different types of cobalt-chrome- coated

Table 3. Types of short stems, families and number of models per family.

Type	Family	Nº of models
A	Head resurfacing	2
B	Neck with collar	2
	Neck with collar and extramedullary support	1
	Ultrashort neck without collar	4
	Ultrashort without collar	3
	Ultrashort without collar and lateral extramedullary support	2
	Ultrashort without collar	3
C	Curved, with collar	2
	Curved, without collar («C» shaped or «banana»)	6
	Curved, without collar, beveled tip	2
	Standard shortened, straight wedge, without collar	4
	Straight, structured, without collar	2
	Straight tapered, unstructured, without collar	3
	Curved, without collar, wedged, tapered *(metaphiseal-engaging)*	2
	Same geometrical design, with or without collar	2
	Custom made short stems (*custom*)	2
Total	16	42

that point. The objections to this proposal include, on the one hand, the fact that the same length cannot be used in an individual 1.85 m tall and in someone 1.60 m tall. On the other hand, although the accepted proximal limit of the metaphysis is the attachment of the hip joint capsule (at the border with the neck area), and the distal limit is located where the metaphysis ends; the problem is: where does the metaphysis end and where does the shaft start?

Table 4. Design variables.

Design variables	Nº of variables
Anatomical zone or region they occupy	3
Overall geometry	11
Cross-sectional geometry	5
Lateral profile	2
Modularity	2
Resurfacing material	4
Major stress transmission zone	13
Type of anchor	2
Total	84

It is evident that the limits between the former regions are defined considering their anatomical and biomechanical features as well as the distribution of trabecular and cortical patterns in each region, which are clearly different in each of the proximal femur segments *(Figure 5)*.

We now recognize the correlation among the external dimensions of the femur (femoral head, total length, offset and external cortices). However, this does not apply to the medullary canal, as the latter has very variable endosteal characteristics that are not proportional to the outer dimensions of the femur.[13]

Table 5. Classification of short uncemented stems by family and nomenclature.

Type	Nomenclature	Example	Brand/Manufacturer
Family: Head resurfacing			
Type	Nomenclature	Example	Brand/Manufacturer
A Cephalo-cervico-metaphyseal	A/1/CSG1/SLP/FH/ PF/HMS/HA		Birmingham Mid-Head Resection by Smith & Nephew
Family: Ultrashort neck with collar			
Type	Nomenclature	Example	Brand/Manufacturer
B Cervico-metaphyseal	B/1/GT1/CSG1/SLP/FN/WC/S/ HMDS/HA		Spiron Threaded Neck Plug By Striker
Family: Ultrashort neck, with collar and extramedullary support			
Type	Nomenclature	Example	Brand/Manufacturer
B Cervico-metaphyseal	B/1/CSG1/ SLP/FH/WC/CM.6/ WES/PF/s/HMDS/Ti		TTP (Thrust Plate Prosthesis) by Zimmer
Family: Ultrashort neck, without collar			
Type	Nomenclature	Example	Brand/Manufacturer
B Cervico-metaphyseal	B/4.1/CSG1/SLP/FN/WoC/ CM.1/ PF/HMDS/Ti		Silent by De Puy
Family: Ultrashort, without collar			
Type	Nomenclature	Example	Brand/Manufacturer
B Cervico-metaphyseal	B/4.3/CSG2/ALP/ CM.1/CM.2/ CM.4/PF/ HMDS/Ti		Proxima by De Puy

Continue Table 5. Classification of short uncemented stems by family and nomenclature.

Family: Ultrashort, without collar and lateral endomedullary support			
Type	Nomenclature	Example	Brand/Manufacturer
B Cervico-metaphyseal	B/4.3/CSG2/SLP/FN/WoC/CM5/ PF7/HMDS/CoCr		CUT A ESKA-Bionik by Orthodynamics
Family: Custom made short stems			
Type	Nomenclature	Example	Manufacturer
B Cervico-metaphyseal (*According to design*)	B/4.3/CSG2/ALP/ CM.1/CM.2/ CM.4/PF/ HMDS/Ti		Custom Short Stem by Stanmore implant & De Puy
Family: Curved, with collar			
Type	Nomenclature	Example	Brand/Manufacturer
C Cervico-metaphyseal-diaphyseal	C/4.2/CSG2/SLP/FN/WC/CM.3/ PDL/PF/HMDS/Ti/HA		CFP* Collum Femori Preserving by LINK
Family: Standard, shortened, without collar			
Type	Nomenclature	Example	Brand/Manufacturer
C Cervico-metaphyseal-diaphyseal	C/3.1/CSG2./ALP/CM.3/DL/PF/ HMDS/Ti		Taper Lock Micropasty by Biomet
Family: Cervico-metaphyseal-diaphyseal without collar and bidirectional profile			
Type	Nomenclature	Example	Brand/Manufacturer
C Cervico-metaphyseal-diaphyseal	C/3.3/CSG4 /SLP/ FN/WoC/ CM.3/ CM.5/PF/HMDS/ CMDS/Ti/CP		Metha by B/Braun

Continue Table 5. Classification of short uncemented stems by family and nomenclature.

Family: Standard shortened straight tapered, without collar, structured

Type	Nomenclature	Example	Brand/Manufacturer
C Cervico-metaphyseal-diaphyseal	C/4.1/CSG4/SLP/CM.3/DL/PF/ HMDS/Ti		CLS Brevius Stem by Zimmer

Family: Straight tapered,without collar, unstructured

Type	Nomenclature	Example	Brand/Manufacturer
C Cervico-metaphyseal-diaphyseal	C C/4.1/CSG2.1/SLP/CM.3/DL/ PF/HMDS/Ti		Balance Microplasty by Biomet

Family: Curved, without collar, wedged, tapered

Type	Nomenclature	Example	Brand/Manufacturer
C Cervico-metaphyseal-diaphyseal	C/3.2/CSG2.1/SLP/FN/ WoC/ CM.3/PDL/PF/HMDS/Ti/HA		Collo Mis by Lima

Family: Short, curved without collar, beveled tip

Type	Nomenclature	Example	Brand/Manufacturer
C Cervico-metaphyseal-diaphyseal	C/3.2/Bd/CSG3/SLP/ FN/WoC/ CM.3/DL/PF/HMDS/ CMDS/Ti		GOT (Global Manufacturing Technology)

Family: Same geometrical design, with or without collar

Type	Nomenclature	Example	Brand/Manufacturer
C Cervico-metaphyseal-diaphyseal	C/4.2/CSG2/SLP/FN/WC/WoC/ CM.3/DL/PF/HMS/ Ti/HA		Primose by Permedic

This *table 6* only shows examples that illustrate the classification methodology used in each stem family. The description of all stems reported here is found in Annex «A».

Table 6. Length of various short stems.

Type of stem	Length (cm)
Spiron	76 - 96
Mini-Hip	90 - 130
Optimys	95 - 139
Profemur Preserve	97 - 125
Nanos	97 - 128
Metha	98 - 123
Coll-Mis	99 - 123
LPI Prime	102 - 107
Taperlock microplasty	112 - 140
Aida	107 - 155
GTS	108 - 159
Fitmore B	113 - 143
SMF	120 - 133
CLS Brevus	123 - 172
CFP	130 - 155

Modified table taken from Fayen H, Shmmin AJ.[3]

Reviewing the femur types proposed by Dorr et al.[14] is very helpful to understand the problem of metaphyseal length variability. They classify them into three types. This typology shows that the variability in engaging and in the metaphyseal/diaphyseal limits results mainly from the type of femoral endosteum *(Figure 6)*. The former suggests that metaphyseal length results mainly from the geometry of the femoral endosteum.

Other authors[7,15] have proposed other definitions of short stem using an anatomical correlation index. For instance, Feyen et al.[7] have defined short stems as those whose total length (D_2) is less than twice the vertical distance between the tip of the greater trochanter and the base of the lesser trochanter (D_1) *(Figure 7)*. The major objection to this proposal is that D_2 is considered as part of the short stem territory, but it involves the overt invasion of the femoral shaft, where any «standard» shaft could be placed.

As we have seen, several different proposals have been made to define a short stem. We did a search on the

Figure 5.

The morphologic features and trabecular patterns of the metaphysis are different than those of the diaphysis, as the latter is filled mainly by bone marrow with predominance of cortical bone.

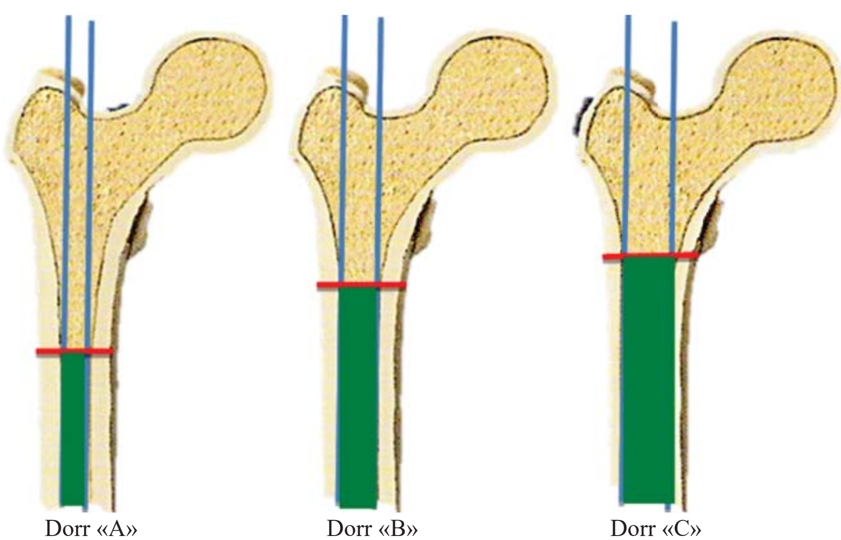

Figure 6.

The distal limits between the metaphysis and the diaphysis are very variable and depend mainly on the characteristics of the femoral endosteum. It is evident that the extension of these regions is different depending on the type of endosteum.

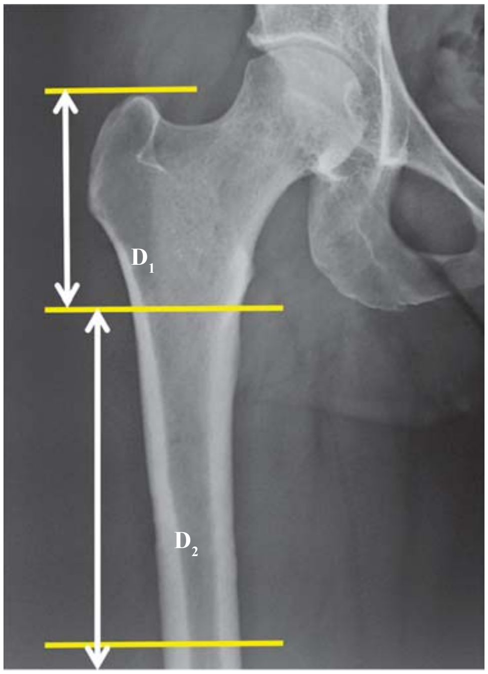

Figure 7. Feyen index. Short stems are those whose total length (D_2) is less than twice the vertical distance between the tip of the greater trochanter and the base of the lesser trochanter (D_1).[3]

definitions of short stem, and although we did not find one that is objection-free, we agree with the one proposed by Gulow.[11] The latter defines short stems are those that occupy the neck and the metaphysis, but we propose to also include those occupying the proximal borderline aspect between the metaphysis and the shaft, regardless of the type of endosteum present. If a stem overtly invades the shaft, then it should not be considered as short.

As regards the second problem, i.e., stem classification, several attempts have been made using various criteria. Some of them coincide on certain aspects, while others do not consider certain variables, but most of them mix different classification concepts and criteria *(Table 7)*.[1,7,16,17,18]

Patent agencies have nomenclature systems that describe the distinctive characteristics of each element to be patented. However, up to now, there is no clinical nomenclature that can name them, so we designed a system that describes in an unequivocal, unique and distinctive way each of the stems. This system also allows us to group them in families. The final goal of such description is to propose a standardized classification that allows comparing the results of the stems. This makes it clinically useful and helps implant developers, manufacturers and analysts assess their results of stems. But it should do so in a rational, orderly way, without mixing concepts and philosophies.

The design of short femoral stems results from many factors, but they should have five basic characteristics defined by the following: the anatomical region they occupy, the geometric design characteristics, the areas where stress transmission occurs, the level at which the proximal femur osteotomy is performed, and the axes that guide their insertion depending on whether the femoral neck is spared or not.

Regarding the anatomical region occupied by stems *(Table 3 and 6)*, only one model occupies part of the femoral head, the neck and part of the metaphysis (Birmingham Mid-Head Resection, by Smith & Nephew), but the rest of them occupy part of the neck (with several cut and angulation levels) and all or part of the metaphysis. Some also occupy part of the shaft, especially the «standard» shortened models.

Considering the geometric design characteristics, the 42 models share 84 design variables *(Table 4)* and transmit stresses according to their varied philosophy or design bases *(Figure 4)*. This huge diversity of morphologic and geometric design features represents the greatest classification difficulty. It is, therefore, necessary to establish a nomenclature system that describes in an easy, unequivocal and distinctive way each of the stems, so that they can be grouped in families and their results can be more easily analyzed *(Table 2)*.

Current short model designs establish a clear difference in the axes that guide their insertion, which is based on the preservation of the femoral neck. Femoral neck sparing stems have to adopt a more anatomical version angle than non-sparing stems. An example of this is the fact that the models with which the traditional resection osteotomy is used and that do not spare the neck are forced to correct the version with modular necks that adjust femoral version.

This communication does not intend to analyze the clinical results of the different short stems described herein, as this is the purpose of a future work that will be based on the scoring and nomenclature proposed.

Conclusions

Short stems are defined as those occupying the neck, the metaphysis and the proximal borderline aspect between the metaphysis and the diaphysis, regardless of the type of the endosteum present. If a stem overtly invades the shaft, then it should not be considered as short.

We identified 42 different models with 84 design variables, manufactured by 20 companies. This model diversity may be grouped into three types and 16 generic families.

To classify them, we propose a nomenclature that describes in an unequivocal, unique and distinctive way each short stem. This way, stems can be grouped in families and the analysis of their results can be made easier.

Conflicts of interest

Felipe Gomez-Garcia, MD, or any member of his immediate family, has no funding or commercial associations that might pose a conflict of interest in connection with the submitted article.

Mariano Fernandez-Fairen, MD, PhD, or any member of his immediate family, has no funding or commercial associations that might pose a conflict of interest in connection with the submitted article.

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Availability of data

All the bibliographical data of this investigation are available to whoever asks for them.

Table 7. Comparison of several short stem classifications.

Author	Criteria	Classification by Types		Remarks
Feyen H[3]	Length, bone resection level, anatomical anchoring area	I	Head resurfacing	Its definition of short stem is based on an anatomical correlation index and combines short stems with standard stems
		II	Mid-head resection	
		III	Short stem (total length less than twice the vertical distance from the tip of GT to the base of LT)	
		IIIA	With subcapital osteotomy	
		IIIB	With «standard» osteotomy	
		IV	Standard stem (total length greater than twice the vertical distance from the tip of the GT to the base of LT)	
		IVA	With metaphyseal fixation only	
		IVB	With metaphyseal and diaphyseal fixation	
		V	With diaphyseal fixation	
GT = Greater trochanter; LT = Lesser trochanter.				
Falez[2]	Grade of bone sparing	1	Collum	Does not provide any lengths, it only mentions the grade of bone sparing
		2	Partial collum with neck preserving osteotomy	
		3	Trochanteric sparing	
		4	Thochanteric harming	
Khanuja[6]	Loading area	1	Femoral neck only	Does not define lengths, it is based on the loading area, the areas they occupy, the stabilization systems, and the overall and cross-sectional geometries. Excludes resurfacing stems
		1A	Wedge-shaped	
	Geometric design	1B	Cylindrical tapered	
		1C	Self-cuting threaded, cylindrical	
		2	Calcar loading	
		2A	Trapezoidal, collarless, double-tapered	
		2B	Rounded with oval shape	
		2C	Threaded cylindrical with collar	
		2D	Thrust plate	
		3	Calcar loading with lateral flare	
		4	Shortened tapered conventional stems	
Gulow[4]	Anchoring zone	1	Resurfacing endoprostheses anchoring on the epiphysis	This classification is not only for short stems, as it mixes them with standard ones
		2	Collum endoprostheses solely anchoring on the metaphysis	
		3	Short collum-preserving stems anchoring on the metaphysis with short anchorage on the diaphysis;	
		4	Conventional stems anchoring on the metaphysis with a long diaphyseal anchorage	
van Oldenrijk[18]	Anchoring zone	1	Resurfacing endoprostheses anchoring on the epiphysis	This classification is not only for short stems, as it mixes them with standard ones
		2	Collum endoprostheses solely anchoring on the metaphysis	
		3	Short collum-preserving stems anchoring on the metaphysis with short anchorage on the diaphysis;	
		4	Conventional stems anchoring on the metaphysis with a long diaphyseal anchorage	
McTighe[10]	Stabilization area	1	Head stabilized	
		1-A	Hip resurfacing	
		1-B	Mid-head stem	
			Neck stabilized	
		2	Short curved stems	
		2-A	Lateral engaging stem	
			Neck Plugs	
		2-B	Metaphyseal stabilized	
		2-C	Neck plugs	
		3	Metaphyseal stabilized	
		3-A	Tapered stems	
		3-B	Bulky/fit and fill stems	
		4	Conventional metaphyseal/diaphyseal stabilized	

Electronic supplementary material

Annex «A»

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Annex «A»
Table 2. Short stems models.

Short stems type «A»
(Cephalo-Cervico-Metaphiseal)

Family: Head resurfacing

Commercial brand	Image	Nomenclature	Manufacturer
BMHR (Birmingham Mild- head Resection)		A/1/CSG1/SLP/FH/PF/HMS/HA Head	Smith & Nephew
BMHR (Birmingham Mild- head Resection)		A/1/CSG1/SLP/FH/PF/HMDS/TI	Smith & Nephew

ShoRT STEms type «B»
(Cervico-metaphiseal)

Family: Ultrashort neck with collar

Commercial brand	Image	Nomenclature	Manufacturer
GOT (Gothemberg osseointegrated Hip)		B/1/GT1/CSG/SLP/ FN/WC/PF/HMDS/Ti	Astra Tech
Spiron threaded neck plug		B/1/GT1/CSG1/SLP/FN/WC/S/ HMDS/HA	Striker

Short stems type «B»
(Cervico-metaphiseal)

Family: Neck with collar and extramedullary support

Commercial brand	Image	Nomenclature	Manufacturer
TTP Thust Plate Prosthesis		B/1/CSG1/ SLP/FH/WC/CM.6/ WES/ PF/s/HMDS/Ti	Zimmer

Short stems type «B»
(Cervico-metaphiseal)

Family: Neck, without collar

Commercial brand	Image	Nomenclature	Manufacturer
Silent		B/4.1/CSG1/SLP/FN/WoC/ CM.1/PF/HMDS/Ti	De Puy
Silent		B/4.1/CSG1/SLP/FN/WoC/ CM.1/PF/HMDS/Ti	DePuy
Primoris™ Neck Replacement		B/2/CSG3/SLP/FN/WOC/ PF/HMDS/ HA	Biomet
TSI™ Neck Plug		B/2/CSG4/SLP/FN/WoC/PF/HMDS/?	Concept, Design & Development,

Short stems type «B»
(Cervico-metaphiseal)

Family: Ultrashort without collar

Commercial brand	Image	Nomenclature	**Manufacturer**
Just Neck		B/4.3/CSG1/SLP/FN/CM1/PF/HMDS/?	Permedica
CUT/ESKA		B/4.3/CSG2/SLP/FN/WoC/CM5/PF7/ HMDS/CoCr	Orthodynamics

Short stems type «B» *(Cervico-metaphiseal)*			
Family: Ultrashort without collar			
Commercial brand	Image	Nomenclature	Manufacturer
Proxima		B/4.3/CSG2/ALP/CM.1/ CM.2/CM.4/PF/HMDS/Ti	De Puy
Proxima		B/4.3/CSG2/ALP/CM.1/CM.2/ CM.4/PF/MDS/Ti	De Puy
Pegasus Modular		B/3.1/CSG2.1/SLP/CM.3/ PF/HMDS/ CMDS/HA	Permedica Manufacturing

Short stems type «C» *(Cervico-metaphiseal with proximal diaphyseal fixation)*			
Family: Standard, shortened, without collar and bidirectional profile			
Commercial brand	**Image**	**Nomenclature**	**Manufacturer**
MAYO		C/3.3/CSG4/SLP/FN/WoC/CM.3/ CM.5/HMDL/Ti	Zimmer
AIDA Short Stem		C/4.3/CSG2/SLP/FN/WoC/CM.3/ CM.5/PF/HMDS/Ti/HA	Implancast
Metha		C/3.3/CSG4 /SLP/ FN/WoC/CM.3/ CM.5/PF/HMDS/CMDS/Ti/CP	Aesculap
Alteon		C/3.3/CSG2.1 /SLP/ FN/WoC/CM.3/ CM.5/PF/HMDS/Ti	Exatech

Short stems type «C» *(Cervico-metaphiseal with diaphyseal fixation)*			
Family: Curved with collar			
Commercial brand	Image	Nomenclature	Manufacturer
Biodynamic hip		C/4.2/CSG2/SLP/FN/WC/CM.3/ PDL/PF/HMDS/CoCr	Biodynamics
CFP (Collum femori Presenrving)		C/4.2/CSG2/SLP/FN/WC/CM.3/ PDL/PF/HMDS/Ti/HA	LINK

Short stems type «C» *(Cervico-metaphiseal with proximal diaphyseal fixation)*			
Family: Short, curved, without collar ("banana")			
Commercial brand	Image	Nomenclature	Manufacturer
Nanos		C/3.2/CSG2.1/SLP/FH/WoC/CM.3/ HMDL/Ti	Smith & Nephew
Minima		C/3.2/CSG2.1/SLP/CM.3/WoC/ PF/PDL/HMDS/CMDS/Ti	Lima
Optimys		C/3.2/CSG2.1/SLP/CM.3/WoC/ PDL/PF/HMDS/Ti/CP	Robert Mathys
Fitmore hip stem		C/3.2/CSG2.1/SLP/CM.3/WoC/ PDL/PF/HMDS/Ti	Zimmer

Collo-Mis		C/3.2/CSG2.1/SLP/FN/WoC/ CM.3/PDL/PF/HMDS/Ti/HA	Lima
MiniHip		C/3.2/CSG2/SLP/FN/WoC/ CM.3/PDL/PF/HMDS/Ti/HA	Corin

Short stems type «C» *(Cervico-metaphiseal with diaphyseal fixation)*			
Family: Short, curved, without collar, beveled tip			
Commercial brand	Image	Nomenclature	Manufacturer
Georgia Apex ARC™ Stem		C/3.2/Bd/CSG3/SLP/ FN/WoC/ CM.3/DL/PF/HMDS/CMDS/Ti	Omnilife Science
MSA Stem		C/3.2/Bd/CSG3/SLP/ FN/WoC/ CM.3/DL/PF/HMDS/CMDS/Ti	GOT (Global Manufacturing Technology)

Short stems type «C» *(Cervico-metaphiseal-diaphisiary with diaphyseal fixation)*			
Family: Standard shortened, straight wedge, without collar			
Commercial brand	Image	Nomenclature	Manufacturer
Accolade II		C/3.1/CSG3/SLP/CM.3/DL/ PF/HMDS/Ti/HA	Stryker
Tri Lock Bone Preservation Stem		C/3.1/CSG3/SLP/CM.3/DL/ PF/HMDS/Ti	Striker

Taper Lock Microplasty		C/3.1/CSG2./ALP/CM.3/DL/ PF/HMDS/Ti	Biomet
Exacta S		C/3.1/CSG2./SLP/CM.3/DL/ PF/HMDS/Ti/HA	Permedica

Short stems type «C» *(Cervico-metaphiseal-diaphisiary with diaphyseal fixation)*			
Family: Standard shortened, straight tapered, without collar metaphiseal-engaging.			
Commercial brand	Image	Nomenclature	Manufacturer
Revelation Micro MAX		C/3.1/CSG2.1/SLP/FH/CM.2/DL/ PF/HMDS/Ti	DJO surgical
Citation Short Stem		C/4.1/CSG2.1/SLP/FN/WC/CM.3/DL/ HMDS/Ti/HA	Styker

Short stems type «C» *(Cervico-metaphiseal-diaphisiary with diaphyseal fixation)*			
Family: Standard shortened, straight tapered, without collar, structured			
Commercial brand	Image	Nomenclature	Manufacturer
GTS hip STEM		C/4.1/CSG4/SLP/CM.3/DL/PF/ HMDS/Ti	Biomet
CLS Brevius Stem		C/4.1/CSG4/SLP/CM.3/DL/PF/ HMDS/Ti	Zimmer

Short stems type «C»
(Cervico-metaphiseal-diaphisiary with diaphyseal fixation)

Family: Straight tapered, without collar, unstructured

Commercial brand	Image	Nomenclature	Manufacturer
AJS Hip Sistem		C/4.3/CSG2.1/ALP/CM.3/DL/PF/HMDS/Ti/HA	Implantcast
Balace microplasty		C/4.1/CSG2.1/SLP/CM.3/DL/PF/HMDS/Ti	Biomet
SMF Short Modular Hip System		C/4.1/CSG3/SLP/CM.3/CM.5/DL/PF/HMDS/CMDS/Ti	Smith & Nephew

Short stems type «C»
(Cervico-metaphiseal-diaphisiary with diaphyseal fixation)

Family: Shortened, straight tapered, without collar, unstructured

Commercial brand	Image	Nomenclature	Manufacturer
Promise		C/4.2/CSG2/SLP/FN/WC/WoC/CM.3/DL/PF/HMSD/Ti/HA	Permedica
Furlong Evolution		C/4.1/CSG2/SLP/FN/WC/WoC/CM.3/DL/PF/HMSD/Ti/HA	JRI Orthopaedic

Short stems type «C»
(Cervico-metaphiseal-diaphisiary with diaphyseal fixation)

Family: Shortened, straight tapered, without collar, unstructured

Commercial brand	Image	Nomenclature	Manufacturer
Custom Short Stem		C/3.1/CSG2.1/SLP/FH/CM.2/DL/PF/HMDS/Ti/HA	Biomet
Ustom Short Stem		B/4.3/CSG2/ALP/CM.1/CM.2/CM.4/PF/HMDS/Ti	Stanmore Implant & DePuy