Short femoral stems with metaphyseal or meta-diaphyseal fitting in total hip arthroplasty: a systematic review

Tatani I.[1], Solou K.[1], Megas P.[1]
[1]*Department of Orthopaedic Surgery and Traumatology, Patras University Hospital, Greece*

ABSTRACT

Background: Great variety of short stem designs have been introduced in the market in order to find the ideal combination of bone and soft tissue preservation, optimal stress distribution, excellent functional outcome and survival rates.
Purpose: Summarize and analyze the published data, in terms of clinical and radiological outcomes, complications, revision rates, and implant survival, on tapered-wedge short femoral stems which have metaphyseal only or metaphyseal-proximally diaphyseal fixation and require conventional neck osteotomy.
Methods: Review of literature databases, using the MEDLINE, Embase, and Web of Science, was conducted based on strict inclusion and exclusion criteria to identify studies reporting clinical and radiological outcomes for this specific type of short femoral stems.
Results: Thirty-six studies involving 3535 patients (3786 hips) with a mean age of 61.3 (27.5-74.42) years in a mean follow up of 45.54 (12-120) months were included. Mean Harris Hip Score improved from 45.72 (27.29-60) to 91.44 (83.1–100). The mean University of California at Los Angeles activity level and mean Merle d'Aubigné functional score was improved from 3.71 (3-3.9) to 6.06 (4.7-7.5) and 10.4 (8.5–11.5) to 17.29 (15.5–17.8) points, respectively. Femoral stem was implanted in neutral coronal alignment in 63.6% hips. A total of 30 studies reported revision rate, which was 0.03% (0-17%) and 12 studies presented component survivorship, which was 99% (96-100%) in average of 5.5 years.
Conclusions: Short, tapered-wedge stems with metaphyseal or meta-diaphyseal fitting demonstrate similar excellent clinical outcomes, survivorship and revision rates with low incidence of complications, as the conventional length or other types of short femoral components. Some concerns regarding the incidence of stress shielding phenomenon and coronal stem malalignment have been raised, requiring further evaluation through long-term studies.

KEYWORDS: Total Hip Arthroplasty; Short Femoral Stems; Metaphyseal Fitting

CORRESPONDING AUTHOR, GUARANTOR

Irini Tatani, MD, PhD
Consultant Orthopaedic Surgeon
Orthopaedic Department, Patras University Hospital
Papanikolaou 1, Rio-Patras, 26504, Greece
Mob: +306948485188
Email: irinitatani@gmail.com

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Introduction

An increased rate of 8% in cementless short stem total conventional hip arthroplasty (THA) has been recorded by Australian registry in 2019 (1). Short stems have been designed with the theoretical advantages of accommodating less invasive surgical techniques, sparing bone and soft tissue, optimizing stress distribution at the proximal femur, minimizing stress shielding effect, reducing the incidence of thigh pain, and simplifying future revisions (2,3). Studies have demonstrated that short stems load better the proximal metaphysis and improve proximal implant fixation, reproducing a biomechanical behavior more similar to the physiological bone, hence, they provide higher osseointegration rates minimizing stress-mediated bone resorption (4,5).

Although the risk of aseptic loosening and intraoperative fractures using short stems is better or comparable to conventional stems, high rates of revision are still reported due to primary instability and pain (4,6). The 15-year cumulative percent of revision for primary THA using short stems was 6.3% compared to 7.8% for conventional femoral stems, in 2020 (1). However, because of the great variability of short stems in terms of design, biomechanics, and principles of fixation, the clinical results should be interpreted with great criticism. In the last decade, tapered-wedge short stems with meta-diaphyseal fixation have been introduced in the market and they have become more popular, aiming to maintain the advantages of short femoral protheses, but additionally to reduce micro-rotation due to meta-diaphyseal fitting (7–9).

There are many classifications of short stems described in the literature. Khanuja et. al. (10) defined a classification system of short stems based on fixation principles and location of proximal loading, with the following categories: femoral neck only, calcar loading, lateral flare calcar loading, and shortened tapered. Feyen et. al. (11) classified the short stems in five categories according to the required level of femoral neck osteotomy and the intended site of primary stability. McTighe et al. (12) advocated a classification system by primary stabilization contact regions, which consists of head stabilized, neck stabilized, metaphyseal stabilized, and conventional metaphyseal/diaphyseal stabilized. Falez et. al. (13) classified short stems based on the level of femoral resection and proposed 5 categories: collum, partial collum with neck preserving osteotomy, trochanter sparing and trochanter harming. Summarizing existing classification systems and accounting for all short stem characteristics, Ǵomez-Garćia et al. (14) presented a nomenclature-coding system. Tournier et. al. (15) proposed a 5-fold classification based on the anchorage zone inside the femur for the French Hip & Knee Society (SFHG).

The purpose of this systematic review is to summarize and critically analyze the published literature focused on short femoral stems which are tapered wedge design (type-4 by Khanuja et. al. (12)), require conventional osteotomy, and have metaphyseal only or metaphyseal-proximally diaphyseal fixation (type IVB by Feyen et. al. (13) and either class 3 or 4 by McTighe et. al. (14)). We particularly aim to assess short stems with these specific characteristics in terms of clinical and radiological outcomes, complications, revision rates, and implant survival.

Methods

This systematic review was designed and conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (16).

A comprehensive electronic search of MEDLINE, Embase, and Web of Science from the earliest available year of indexing until October 2021 was conducted. We screened databases by using the following keywords and their combinations: short stem, conventional osteotomy, tapered-wedge design, new generation, meta-diaphyseal fixation, metaphysis and diaphysis fixation, Tri-Lock BPS (Tri-Lock Bone Preservation Stem), Taperloc, Taperloc Microplasty, Accolade II, Accolade 2, Centpillar TMZH, Centpillar GB, Centpillar, MINIMA S, MINIMA Lima, Optimys, Optimys Robert Mathys, Fitmore, Exacta, Exacta S, GTS stem, GTS Biomet, CLS Brevius, CLS stem, AJS Implantcast, Balance Biomet, Balance Microplasty, Symbios SPS, Symbios. Following the electronic search, we carried out supplementary manual research of the reference lists of all retrieved articles to identify potential eligible

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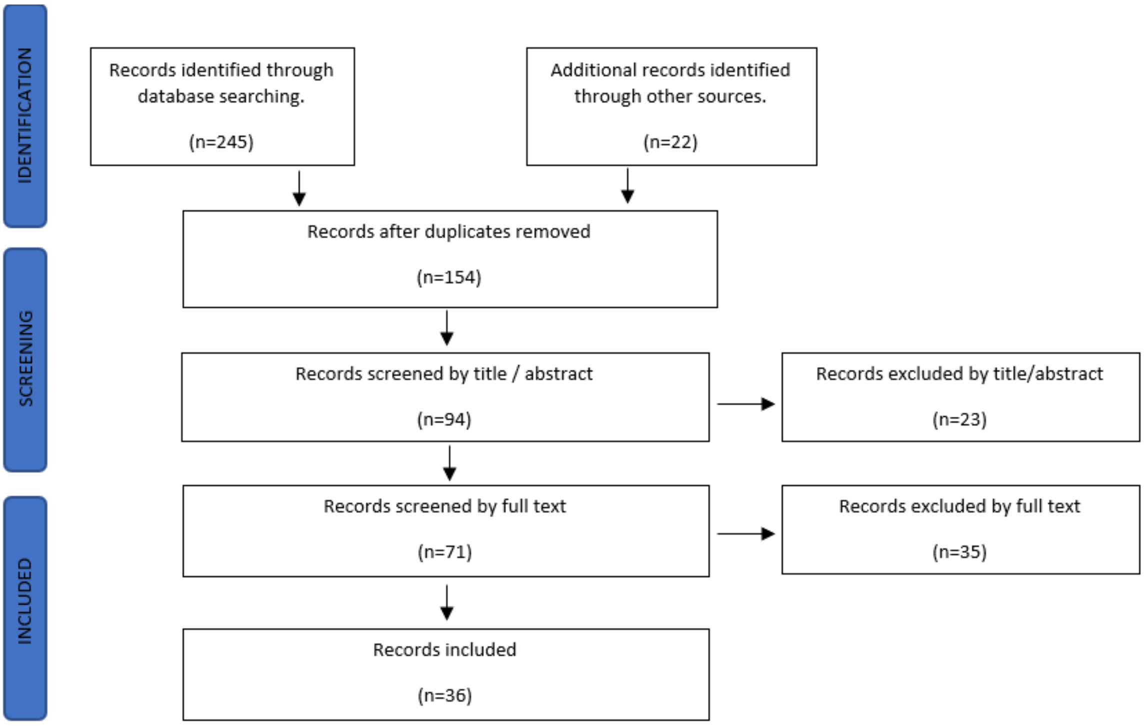

Figure 1

studies. Abstracts of all citations were screened, and full texts of articles were assessed to decide on inclusion of relevant studies. The attrition flowchart is shown in Figure 1.

The authors independently review the articles, extracting data relating to the design of the study, the period of study, case selection, the assessment of outcome, the demographic characteristics of the patients, the follow up, and femoral prothesis type. The inclusion criteria for this systematic review were as follows: (I) reporting THA with a short, tapered-wedge, meta-diaphyseal fitting stem, which required conventional osteotomy; (II) retrospective or prospective studies including randomized controlled trials, non-randomized trials, cohort studies, case–control studies, and case series studies; (III) comparative studies of femoral stems, which provide clear separation of data; (IV) at least one functional assessment score; (V) a minimum of 24 months follow up; (VI) the language of the publications was limited to English. The exclusion criteria were as follows: (I) comparative studies of stems without clear separation of data; (II) comparative studies with subgroups of the same prothesis; (III) nonhuman subjects; (IV) revision surgery; (V) papers not related to the research item. All relevant studies were assessed according to their Levels of Evidence (LOE) based on the 2011 Oxford Centre for Evidence-based Medicine(17). Data were expressed with mean ± standard deviations (SD) and range of minimum and maximum for continuous variables and with number of cases or percentage for categorical variables.

Results

A total of 36 studies were identified, following the research protocol, between 2014 and 2021. There were 5 randomized control trials (LoE I), 9 prospective cohort studies (LoE II), 1 prospective comparative study (LoE II), 7 retrospective cohort studies (LoE III), 4 retrospective comparative studies (LoE III), 5 prospective observational studies of case series (LoE IV), 5 retrospective observational studies of case series (LoE IV). A total of 3786 stems, used

TABLE 1.

Patients' Demographic data

STUDY	Stem type	LoE	No Hips	No Patients	Males	Females	Mean age (years)	Mean body mass index (kg/m2)	Dorr A/B/C	Duration of follow-up (months)
(Hayashi *et al.*, 2016)	Trilock BPS	II	65	65	11	54	65.1±10.4	23.4±3.5	3/58/4	24
(Hayashi *et al.*, 2017)	Trilock BPS	II	44	44	22	22	65.0±10.3	23.8±3.8	N/A	24
(Hayashi et al., 2020)	Trilock BPS	III	222	222	36	186	65.3±10.1	23.9±3.9	N/A	63.6
(Zhen *et al.*, 2021)	Trilock BPS	IV	42	35	27	8	27.5±3.7	20.2 (16.8–23.2)	0/0/42	66±13.2
(Ulivi *et al.*, 2017)	Trilock BPS	III	163	163	59	104	74.42 (44-90)	26.88 (16.4-38.1)	39/116/8	84
(Albers *et al.*, 2015)	Trilock BPS	II	123	119	55	64	64.6 (34-89)	N/A	97/26/0	60 (49.2-66)
(Slullitel *et al.*, 2020)	Trilock BPS	I	46	46	22	24	60.4±10.1	27.4±2.9	N/A	48
(Amendola *et al.*, 2017)	Trilock BPS	II	238	238	104	134	64 (21–91)	30 (16–56)	N/A	36 (24-60)
(Tatani *et al.*, 2020)	Trilock BPS	I	45	45	16	29	63.89±8.56	28.45±4.95	12/28/5	48
	Minima S		45	45	23	22	63.49±8.16	28.52±4.31	14/24/7	48
(Guo *et al.*, 2021)	Trilock BPS	III	104	84	35	49	53.12±2.32	25.16±2.20	53/18/13	48.23±2.91
(Peng et al., 2021)	Trilock BPS	IV	55	55	42	13	49.8 (25–73)	23.8 (17.9–33.8)	10/43/2	42.5 (36–48)
(Schilcher et al., 2017)	Taperloc Microplasty	I	30	30	17	13	60.6±4.7	26.3±3.9	21/9/0	48
(Saragaglia et al., 2020)	Taperloc Microplasty	III	119	119	81	38	58.8±11	27.9±5.2	57/62/0	61±8
(Nahas et al., 2018)	Taperloc Microplasty	IV	196	196	105	91	59 (21–78)	N/A	N/A	36 (5 -75)
(Molli et al., 2012)	Taperloc Microplasty	III	269	246	111	135	63 (27–91)	30.1 (19–60)	N/A	29.2 (0.8-62.2)
(Gallart et al., 2019)	Taperloc Microplasty	III	40	32	20	12	50 (28-66)	27 (16.0–33.0)	12/19/9	36.5 (26 - 68)
(Lombardi et al., 2021)	Taperloc Microplasty	IV	92	92	41	51	63.2±10.1	30.8±6.8	N/A	54 (24-72)
(Hayama et al., 2020)	Taperloc Microplasty	III	257	235	34	201	63 (41–86)	N/A	N/A	53 (24-83)
(Uçan et al., 2021)	Taperloc Microplasty	I	40	20	8	12	52±14.1	24.9±3.2	N/A	28.7±3.8
(Pogliacomi et al., 2020)	Taperloc Microplasty	II	60	60	24	36	68.4 (58–83)	27.5 (23–31)	N/A	60
(Uemura et al., 2021)	CentPillar GB	III	198	181	11	170	56 (18–91)	22.9 (13.6–35.5)	131/88/3	13.1
	CentPillar TMZF		24							
(Nam et al., 2019)	Accolade II	II	31	31	24	7	52.6±6.5	27.9±3.9	N/A	24
(Sariali et al., 2017)	Symbios SPS	II	154	154	97	57	58.8±13.5	26.5±4.4	N/A	60
(Tostain et al., 2019)	Symbios SPS	IV	61	61	16	45	74 (44–83)	30.5	N/A	120
(Graceffa, 2016)	CLS Brevius	III	170	155	75	80	61.8 (42-67)	N/A	N/A	32 (24-44)
(Drosos et al., 2020)	Minima S	III	61	61	19	42	56±11.1	31.2±4.9	11/48/2	33.4 (12-57)
(Morales De Cano et al., 2014)	GTS Biomet	IV	81	80	55	25	64.8 (43–78)	N/A	N/A	16 (6-24)
(Thalmann et al., 2019)	Fitmore	II	96	96	58	38	62.32±9.97	N/A	79/17/0	60
(Acklin et al., 2016)	Fitmore	II	28	28	19	9	64 (22–75)	26 (19–36)	N/A	24
(Maier et al., 2015)	Fitmore	IV	100	100	55	45	59 (19–79)	N/A	N/A	39.6 (24-52.8)
(Freitag et al., 2016)	Fitmore	I	57	57	36	21	56.8±10.2	29.7±4.8	N/A	12
(Hochreiter et al., 2020)	Optimys	IV	46	46	21	25	65.7±9.3	N/A	N/A	24.1
(Djebara et al., 2021)	Optimys	III	47	47	22	25	66.8±6.4	26±3.2	N/A	12
(Kutzner et al., 2019)	Optimys	IV	201	162	89	73	63.5 (3.4–88)	N/A	N/A	61.7 (57.2–83.7)
de Waard et al., 2021)	Optimys	II	34	34	13	21	60	27	N/A	24
(Donner et al., 2019)	Optimys	IV	102	51	29	22	63.1 (36.7-76.8)	27.6 (19.6-41.8)	N/A	62.4 (57.6-75.6)

LoE – Level of Evidence

for primary THA, were included for analysis. The mean follow-up was 45.54 months, ranged between 12 and 120 months.

Tri-Lock Bone Preservation stem was used in 1147 primary THAs, in 11 studies and Taperloc Microplasty (Microtaperloc; Biomet, Inc, Warsaw, IN, USA) was used in 1103 hips, in 9 studies. 281 primary THAs with Fitmore stem (Zimmer Biomet, Winterthur, Switzerland), in 4 studies, were recorded and 430 hips received Optimys (optimys, Mathys Ltd., Bettlach, Switzerland), in 5 studies. Accolade II (ACCOLADE II, Stryker Orthopaedics, Mahwah, NJ, USA), Symbios SPS (SPS-Modular®; Symbios, Yverdon-les-Bains, Switzerland) and GTS (Biomet)

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were implanted in 31, 215 and 81 hips, respectively. 170 CLS Brevius (Zimmer GmbH, Winterthur, Switzerland), 106 Minima S stems (Lima Corporate, Udine, Italy), 222 CentPillar stems (CentPillar-GB and CentPillar-TMZF, Stryker Orthopaedics) have been recorded in primary THAs.

Demographic data. A total of 3786 hips and 3535 patients were reported in 36 studies. Mean age was 61.3, fluctuated between 27.5 and 74.42 years old. There were 1532 men and 2003 women. Information about mean body mass was available for 2346 patients, with a mean value of 27.1 kg/m2, ranged between 20.2 and 31.2 (kg/m^2). Dorr femoral bone classification was reported in 14 studies, 45.3% of femurs were type A, 46.7% were type B and 7.9% type C. Demographic data are presented on Table 1.

Clinical Outcomes. Harris Hip Score (HHS) at the final follow up was demonstrated in 28 studies. The mean Harris Hip Score (HHS) preoperatively was 45.72 (27.29 - 60), improving at follow-up to 91.44 (83.1 – 100) points. The mean HHS difference was 45.54 (32.3 - 69.9) points. Mean UCLA activity was reported in 8 studies and ranged between 3.71 (3 - 3.9) preoperatively and 6.06 (4.7 - 7.5) points at the last follow up. Merle d'Aubigné functional score was used in 4 studies with a mean value 10.4 (8.5 – 11.5) and 17.29 (15.5 – 17.8) points preoperatively and at the last follow up, respectively. Two studies reported a mean value of 48.17 and 92.31 points preoperatively and at the last follow up, respectively, based on the Japanese Orthopedic Association Score (JOA-S). Lastly, de Waard et. al. (18) described function by using Hip Disability and Osteoarthritis Outcome Score (HOOS) and reported a mean value of 27 preoperatively, improving to 87 postoperatively. All reported functional outcomes are demonstrated on table 2.

Regarding pain, Pain Visual Analogue Scale (VAS) was reported in 9 studies with mean values fluctuating between 6.45 (4.5-9.25) and 1.9 (0.1-5.9) preoperatively and at last follow up, respectively. Thigh pain was recorded in 23 studies, with a mean incidence of 6.02%, ranged between 0.51-20.1%. However, only in 4 studies, thigh pain classified as mild, moderate and severe in 19.4%, 7.9%, 2.6%, respectively for a total of 528 hips. Lastly, it has been demonstrated by Graceffa et. al. (19) that no patients reported thigh pain after primary THA with CLS Brevius, but 7% (12 patients) presented with severe trochanteric bursitis at one-year follow-up, which resolved in all but 3 cases till the last follow up.

Implant survival. Regarding survival rates of tapered-wedge short meta-diaphyseal fitting stems, which require conventional osteotomy, twelve studies reported survivorship rates at final follow-up. Overall combined component survivorship for these studies was 99% (96-100%) in average of 66.3 months for 1636 short stems (Table 3).

Revision Rate. In 30 of 36 reviewed studies, revision surgeries and complications have been described and presented on Table 3. The mean revision rate was 0.03%, fluctuated between 0% and 10.7%. The most frequent cause of revision was deep infection or sepsis reported in 7 (0.2%), followed by recurrent dislocation in 4 (0.12%) and periprosthetic fractures in 4 (0.12%). Least frequent causes of revision were aseptic loosening in 3 (0.09%), severe or unidentified thigh pain in 2 (0.06%), and major subsidence in 2 (0.06%). In 774 primary THAs using Tri-Lock BPS, 2 (0.25%) recurrent dislocations, 1 (0.13%) aseptic loosening, 1 (0.13%) infection, one case of 5mm subsidence (0.13%) and one case of severe thigh pain (0.13%) were recorded as causes of revision. Of 1103 primary THAs with Taperloc Microplasty, 5 (0.45%) cases were revised due to periprosthetic fractures (0.18%), recurrent dislocation (0.09%), deep infection (0.09%), and sepsis (0.09%).

Regarding most frequent complications, dislocation was noted at 0.57%, deep infection at 0.39%, deep venous thrombosis at 0.3%, intraoperative femoral fracture at 0.24%, severe thigh pain at 0.21%, and periprosthetic femoral fracture at 0.12%.

Radiological outcome. Femoral stem alignment recorded in 12 studies, nine out of them reported a neutral coronal alignment in 63.6% hips (range 1.2%-96%). Femoral components were placed varus in 14% (1.8%-60%) and valgus in 22% (1.8%-67.5%), respectively (Table 4). The mean alignment deviations from the neutral axis ranged between -1.4^o to 1.99^o. Thirteen studies assessed the incidence of stress shielding phenomenon in 1695 hips; it was

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TABLE 2.

Clinical outcomes in the reviewed studies

STUDY	Stem Type	No (hips)	HHS PRE	HHS POST	UCLA pre	UCLA post	Merle pre	Merle post	OHS pre	OHS post	JOA pre	JOA post	HOOS pre	HOOS post	WOMAC pre	WOMAC post
(Hayashi *et al.*, 2016)	Trilock BPS	65	N/A	90.4±8.6	N/A	5.9±1.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Hayashi *et al.*, 2017)	Trilock BPS	44	N/A	89.4±9.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Hayashi et al., 2020)	Trilock BPS	222	N/A	90.1±6.1	N/A	6.4±1.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Zhen *et al.*, 2021)	Trilock BPS	42	48.0±8.0	87.0±9.0	3.0±0.5	7.5±0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Ulivi *et al.*, 2017)	Trilock BPS	163	27.29±4.612	97.28±9.044			N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Albers *et al.*, 2015)	Trilock BPS	123	41.9±15.2	84.5±12.6	3.9±2.1	5.8±2.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Slullitel *et al.*, 2020)	Trilock BPS	46	PAIN (17.5±7.19) FUNCTION (27.7±7.64)	PAIN (35.6±8.43) FUNCTION (42.0±5.77)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	PAIN (47.3±17.7) STIFFNESS (43.8±20.7) FUNCTION (47.0±17.1)	PAIN (87.2±16.2) STIFFNESS (78.5±21.5) FUNCTION (87.2±14.4)
(Amendola *et al.*, 2017)	Trilock BPS	238	46±16	88±13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Tatani *et al.*, 2020)	Trilock BPS	45	46.63 (11.2)	95.38 (2.98)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	66.42±13.4	8.2±3.13
	lima	45	48.8 (12.35)	96.03 (3.56)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	66.36±15.71	7.49±3.23
(Guo *et al.*, 2021)	Trilock BPS	104	45.32±3.42	93.33±4.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	54.04±10.2	5.58±2.32
(Peng et al., 2021)	Trilock BPS	55	48.13±9.66	96.84±5.60	N/A	N/A	N/A	N/A	36.15±8.80	15.33±3.12	N/A	N/A	N/A	N/A	50.04±9.40	3.27±3.36
(Schilcher et al., 2017)	Taperlock Microplasty	30	52 (31-65)	100 (56-100)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	34 (0-69)	94 (47-100)
(Saragaglia and Orfeuvre, 2020)	Taperloc Microplasty	119	N/A	N/A	N/A	N/A	11±2.3	17.8±0.8	42.5±7	13.1±3.5	N/A	N/A	N/A	N/A	N/A	N/A
(Nahas et al., 2018)	Taperloc Microplasty	196	N/A	N/A	N/A	N/A	N/A	N/A	21	45	N/A	N/A	N/A	N/A	N/A	N/A
(Molli et al., 2012)	Taperloc Microplasty	269	49.9	83.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Gallart et al., 2019)	Taperloc Microplasty	40	N/A	N/A	N/A	N/A	11.5 (11.1–12.8)	17.5 (17.2–17.9)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Lombardi et al., 2021)	Taperloc Microplasty	92	52.5	84.8	N/A	5.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Hayama et al., 2020)	Taperloc Microplasty	257	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	49	89	N/A	N/A	N/A	N/A
(Uçan et al., 2021)	Taperloc Microplasty	40	32.8±8.5	88.9±7.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Pogliacomi et al., 2020)	Taperloc Microplasty	60	30.2 (19–41)	83.4 (76–90)	N/A	N/A	N/A	N/A	16.4 (12–28)	44.3 (37–46)	N/A	N/A	N/A	N/A	61.1 (52–84)	10.5 (8–15)
(Uemura et al., 2021)	CentPillar GB	198	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	47	97	N/A	N/A	N/A	7.6
	CentPillar TMZF	24														
(Nam et al., 2019)	Accolade II	31	53.3+16.8	86.4±20.8	N/A	7.3±1.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Sariali et al.,2017)	Symbios SPS	154	N/A	97±7	N/A	N/A	N/A	N/A	N/A	57±6	N/A	N/A	N/A	N/A	N/A	N/A
(Tostain et al., 2019)	Symbios SPS	61	43 [35–50]	91 (77–96)	N/A	N/A	8.5 (7–10)	15.5 (14-16.5)	N/A	17.2	N/A	N/A	N/A	N/A	N/A	N/A
(Graceffa et al., 2016)	CLS Brevius	170	32 (9-58)	92 (75-100)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Drosos et al., 2020)	Minima S	61	58.7±13.5	95.1±4.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Morales De Cano et al., 2014)	GTS Biomet	81	N/A	N/A	N/A	N/A	10 (8–14)	17.4 (12-18)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Thalmann et al., 2019)	Fitmore	96	59.2±15.6	93.8±10.25	N/A	N/A	N/A	N/A	N/A	41.02 (9.07)	N/A	N/A	N/A	N/A	N/A	N/A
(Acklin et al., 2016)	Fitmore	28	60 (30–80)	99 (83–100)	N/A	N/A	N/A	N/A	23 (10–37)	46 (42–48)	N/A	N/A	N/A	N/A	N/A	N/A
(Maier et al., 2015)	Fitmore	100	56 (14 -80)	94 (62 -100)	3.7(2–7)	6.7 (2–10)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	93 (58.3–100)
(Freitag et al., 2016)	Fitmore	57	52±13	85±14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.6±2.6	1.7±2.2
(Hochreiter et al., 2020)	Optimys	46	57.2±20	97.2±4.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0
(Djebara et al., 2021)	Optimys	47	58.7±4.8	95.2±2.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Kutzner et al., 2019)	Optimys	201	45.6 (7-88)	97.8 (65-100)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A
de Waard et al., 2021)	Optimys	34	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	27 (17-40)	87 (74-94)	N/A	N/A
(Donner et al., 2019)	Optimys	102	44.2±15.2	97.8±5.3	3.8±2.0	4.7 (2.0-10)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	98.0 ± 5.8	N/A

HHS – Harris Hip Score, PRE – Preoperative, POST – postoperative, UCLA – University of California at Los Angeles activity level, Merle – Merle d'Aubigné functional score, OHS – Oxford Hip Score, JOA- Japanese Orthopedic Association Score, HOOS – Hip Disability and Osteoarthritis Outcome Score, WOMAC – Western Ontario and McMaster Universities Arthritis Index.

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grade 1 in 56.6% hips, affecting mostly Gruen zones 1 and 7. Grade 2 was noted in 12.7% hips, while grade 3 in 0.47%. Only one hip (0.059%) implanted with the CentPillar stem showed grade 4 stress shielding effect at last follow up (20) (Table 5). In 8 studies, all femoral components were considered osseointegrated, and only in one study the osseointegration rate was 96.4% (21). The incidence of heterotopic ossification ranged between 0 and 19%, according to 10 of the reviewed studies. From sixteen studies reported on the incidence of radiolucent lines, only 9 studies noted the presence of radiolucent lines under 1 mm in 17% hips (range 0.61%-45.5%). Two studies demonstrated calcar osteolysis, in 5% and 75% hips implanted with the Symbios SPS (22) and Fitmore (23) femoral stems, respectively. The mean incidence of aseptic loosening at the last follow up in a total of 1263 hips within 11 studies was 0.02%. Subsidence of femoral component noted by 20 authors with a mean value of 0.36 mm (0 - 1.93 mm). In 6 cases, a major subsidence (>2 mm) was noted, and the femoral component had to be revised in two of them. Each radiological parameter described in the included studies is shown in Table 5.

Discussion

Our study systematically reviewed and assessed all available studies presenting the clinical and radiological outcomes, survival rates, revisions and complications of several short femoral components with metaphyseal or meta-diaphyseal fixation that require conventional neck osteotomy. Since most of the currently available short stems of this category are relatively new with short term clinical performance, clinical evidence with more than 24 months follow up was limited to a small number of studies. Therefore, it was not surprising that studies on some brands have not been included in this review.

As THA has expanded its indications and is being performed in younger and more active patients, the need for an optimized femoral prothesis for bone and soft tissue preservation is of utmost importance. A growing interest towards short versions of uncemented femoral implants is recorded in the current literature as an effort to address this issue. The fact is that a heterogeneous group of short femoral prostheses with differences in operative technique, design philosophy and method of fixation has emerged in clinical practice, and long-term data are still awaited. In this systematic review, we concentrated on short stems with metaphyseal only or metaphyseal-proximally diaphyseal fitting and conventional neck osteotomy, which gain popularity in the market according to registries. Furthermore, most orthopaedic surgeons are familiar with the implantation process required for this type of prostheses that presents similarities to that of a conventional stem. In the UK during 2020, Accolade II was used in 13% of primary THAs, moreover an increased trend in the use of Taperloc Microplasty, Tri-Lock BPS, Symbios SPS has been observed (25). The use of Accolade II and Taperloc Microplasty has been increased the last five years in Australia (1) and an increasing trend is also observed in National Joint Registry data (25). According to the Swiss Registry, an increased trend in the use of Fitmore, Optimys and Tri-Lock BPS femoral stems was noticed (26).

According to a previous systematic review on short metaphyseal loading cementless stems, similar improvement in clinical and radiological outcomes was noted compared to conventional length implants (24). However, coronal stem malalignment, stress shielding effect, cortical hypertrophy or implant's subsidence as well as their consequence of fracture risk and aseptic loosening still remain a concern with certain short stem designs (5).

In this systematic review, a total of 3786 hips in 3535 patients were analyzed. The mean age of patients was 61.3 (27.5-74.42) years old. Two third of the included studies reported a mean age above 60 years old, with two out of them reported cohorts with a mean age of 74 years old, which is higher than the reported average between conventional short stems (5,24). Only Zhen et al. studied young adult osteoporotic patients with mean age of 27.5 years old, who had Dorr type C femur, investigating the wide spectrum of Tri-Lock BPS prothesis. On the contrary, the majority of included studies reported high incidence of Dorr type A and B femurs, 45.3% and 46.7%, respectively, and only 7.9% type C (3,27). Patients with Dorr type C femur are more

TABLE 3.

Component Survivorship, Revision and Complication rates

Study	Stem Type	No Hips	Survival Rate	Revision	Reason for revision	Complications
(Ulivi *et al.*, 2017)	Trilock BPS	163	99%	1(0.61%)	1 recurrent dislocation	1 dislocation
(Albers *et al.*, 2015)	Trilock BPS	123	99.2%	1 (0.81%)	1 >5mm subsidence	2 Intraoperative great trochanter fractures 2 dislocations 1 subsidence
(Slullitel *et al.*, 2020)	Trilock BPS	46	N/A	1 (2.17)	1 aseptic loosening	1 calcar crack 1 femoral nerve palsy 5 thigh pain 1 aseptic loosening
(Amendola *et al.*, 2017)	Trilock BPS	238	N/A	2 (0.8%)	1 infection 1 tight pain	2 infections 2 heteropic ossification 1 tight pain
(Tatani *et al.*, 2020)	Trilock BPS	45	N/A	0		2 superficial infections
	Minima S	45	N/A	0		1 superficial infection
(Guo *et al.*, 2021)	Trilock BPS	104	98.80%	1 (0.96%)	1 recurrent dislocation	1 dislocation 3 pneumonias 2 limp nerve numbness 1 intraoperative periprosthetic femoral fracture
(Peng et al., 2021)	Trilock BPS	55	100%	0		0
(Schilcher et al., 2017)	Taperloc Microplasty	30		0		0
(Saragaglia et al., 2020)	Taperloc Microplasty	119	100%	1 (0.84%)	1 recurrent dislocation	2 deep venous thrombosis 1 pulmonary embolism 3 dislocations
(Nahas et al., 2018)	Taperloc Microplasty	196	N/A	1 (0.5%)	1 periprosthetic fracture	3 dislocations 1 subsidence 1 periprosthetic fracture
(Molli et al., 2012)	Taperloc Microplasty	269	100%	1 (0.37%)	1 sepsis	1 intraoperative fracture type 3 debridement wound tissue 2 cup revision loosening 1 sepsis
(Gallart et al., 2019)	Taperloc Microplasty	40	N/A	0		1 posterior femoral cortical perforation 1 infection 1 dislocation 1 subsidence
(Lombardi et al., 2021)	Taperloc Microplasty	92	N/A	2 (2.17%)	1 periprosthetic fracture 1 infection	1 periprosthetic fracture 1 infection 1 non healing wound
(Hayama et al., 2020)	Taperloc Microplasty	257	N/A	0		1 intraoperative great trochanter fracture 1 acute infection 1 dislocation
(Uçan et al., 2021)	Taperloc Microplasty	40	N/A	0		2 intraoperative periprosthetic fracture
(Pogliacomi et al., 2020)	Taperloc Microplasty	60	N/A	0		1 intraoperative fracture 1 subsidence
(Uemura et al., 2021)	CentPillar GB	198	99%	2 (0.9%)	1 aseptic loosening 1 infection	1 intraoperative periprosthetic fracture 1 aseptic loosening 1 infection 2 subsidence
	CentPillar TMZF	24				
(Sariali et al., 2017)	Symbios SPS	154	97%	0		1 dislocation 1 lower limb discrepancy 2 intraoperative periprosthetic fractures
(Tostain et al., 2019)	Symbios SPS	61	96%	3 (4.91%)	2 periprosthetic fracture 1 dislocation	1 dislocation 2 infections 2 periprosthetic fractures
(Graceffa, 2016)	CLS Brevius	170	99.4%	1 (0.6%)	1 major subsidence	3 calcar cracks 2 dislocations 5 DVT 1 subsidence
(Drosos et al., 2020)	Minima S	61	N/A	0		1DVT
(Morales De Cano et al., 2014)	GTS Biomet	81	N/A	0		1 intraoperative femoral calcar crack
(Thalmann et al., 2019)	Fitmore	96	99%	0		1 dislocation 1 deep infection 1 hematoma

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TABLE 3.

Component Survivorship, Revision and Complication rates

(Acklin et al., 2016)	Fitmore	28	N/A	3 (10.7%)	1 aseptic loosening 1 unidentified thigh pain 1 infection	1 aseptic loosening 1 unidentified thigh pain 1 infection
(Maier et al., 2015)	Fitmore	100	100%	0		1 hematoma
(Hochreiter et al., 2020)	Optimys	46	N/A	0		1 perioperative dislocation
(Djebara et al., 2021)	Optimys	47	N/A	0		0
(Kutzner et al., 2019)	Optimys	201	N/A	1 (0.5%)	1 deep infection	1 intraoperative great trochanter fracture 1 DVT 1 dislocation 1 infection
(de Waard et al., 2021)	Optimys	34	N/A	1 (2.9%)	1 deep infection	1 infection
(Donner et al., 2019)	Optimys	102	N/A	0		1 intraoperative avulsion of great trochanter 1 DVT 3 seromas

prone to distal stem stabilization, and thus there are less possibilities to achieve rigid primary fixation and bone ingrowth when using metaphyseal fitting short stems, which is in alignment with clinical and biomechanical studies (28–34).

In terms of functional outcome, our results indicate that the shortened tapered wedge stems, with metaphyseal only or metaphyseal-proximally diaphyseal fitting provide excellent results in short- and mid- term follow up. This review found a mean HHS improvement of 45.54 points, from 45.72 (27.29 – 60) preoperatively to 91.44 (83.1-100) postoperatively at 45.54 months follow up. These results are similar with other systematic reviews and metanalysis of short stem studies (10,13,24) and conventional length prothesis studies (35,36). Guo et al. (8) compared Tri-Lock BPS with conventional standard Corail stem (Johnson & Johnson, Warsaw, IN,USA) demonstrating no statistically significant difference in WOMAC score between the two groups, 5.58 ± 2.32 and 6.48 ± 2.32 in 4 years follow up, respectively, beside lower occurrence of thigh pain in the first group (no patients), while 5% in the second one. Higher rate of thigh pain in conventional group (p=0.003), due to tight distal fit of the stem, was presented by Pogliacomi et al. (33). Amendola et. al. (12) assessed the results of the Tri-Lock BPS in 261 hips at a mean follow up of three years and showed high incidence (22.6% of patients) of thigh pain although the HHS improved from 47 to 88. To our knowledge, there are no previous studies on metaphyseal fitting short stems, reporting such high rates of thigh pain. In this review, low incidence of thigh pain (6.02%) was observed. Lastly, Hayashi et al. (30) in their risk factor analysis regarding the incidence of thigh pain following total hip arthroplasty with short, tapered-wedge stem showed that the profile of patients with thigh pain consists of higher UCLA activity, type C Dorr femoral bone shape and contact between stem tip and cortical bone.

Regarding coronal alignment of short stems, a higher rate of coronal misalignment has been observed compared to the conventional standard length femoral implants (10). Lidder et al. (24) presented 90% of neutral alignment between different types of short stems. On the contrary, in this systematic review, 12 studies reported on stem alignment with only 63.6% of the components being in neutral position at the final follow up. In our previous comparative study between Tri-Lock BPS and Minima S stem, a high rate of deviations from neutral position was demonstrated, with the discrepancies being more evident in Minima S group, which is explained by its shorter design and its limited extension to the proximal diaphysis. However, functional outcomes and survivorship were not affected, between the misaligned components compared to those in neutral position, in accordance with previous reports of Albers et al. and Ulivi et al. (37–39).

Stress shielding effect is theoretically limited in

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TABLE 4.

Coronal alignment of femoral components

STUDY	Stem Type	No Hips	Neutral	Varus	Valgus
(Zhen *et al.*, 2021)	Trilock BPS	42	40 (95.2%)	1 (2.3%)	1 (2.3%)
(Ulivi *et al.*, 2017)	Trilock BPS	163	2 (1.2%)	56 (34.3%)	105 (64.4%)
(Albers *et al.*, 2015)	Trilock BPS	123	29 (23.0%)	11 (8.9%)	83 (67.5%)
(Slullitel *et al.*, 2020)	Trilock BPS	46	41 (89%)	4 (8%)	1 (2%)
(Tatani *et al.*, 2020)	Trilock BPS	45	16 (35.6%)	23 (51.1%)	6 (13.3%)
	lima	45	0	27 (60%)	18 (40%)
(Guo *et al.*, 2021)	Trilock BPS	104	74 (88%)	8 (10%)	2 (2%)
(Peng et al., 2021)	Trilock BPS	55	53 (96.4%)	1 (1.8%)	1 (1.8%)
(Hayama et al., 2020)	Taperloc Microplasty	257	246 (96%)	0	11 (4%)
(Graceffa, 2016)	CLS Brevius	170	150 (88%)	16 (9.4%)	4 (2.3%)
(Uçan et al., 2021)	Taperloc Microplasty	40	8 (20%) (− 1.4° ± 3.1)		
(Pogliacomi et al., 2020)	Taperloc Microplasty	60	0.8° (0.0°–1.5°)		
de Waard et al., 2021)	Optimys	34	–0.02 (–0.21-0.17)		

shortened tapered-wedge stems due to more natural biomechanical loading, and more pronounced proximal load transfer. However, comparative studies of short femoral implants and conventional femoral designs note evidence of bone resorption, which is less at Gruen zone 1 and 7 in the case of short stems (5,8,36,40). In 14 studies, included in our review, estimated cumulative combined component stress shielding effect noted in 69.7% affecting especially Gruen 1 and 7 regions. Drosos et al. (41) studying Mínima S component observed stress shielding of grade 1 in all patients, without affecting functional outcome. Amendola et. al. (42) reported similar findings in a series of 212 Tri-Lock BPS implanted hips. Kutzner et. al. (43) demonstrated as well high incidence of proximal bone remodeling due to stress shielding (42.3% bone resorption), particularly in Gruen zones 1, 2 and 7, which was interpreted by the lack of a distal third point of stabilization and by varus alignment of the implants. Nevertheless, biomechanical studies have shown that the incidence of stress shielding depends on the proximal femoral morphology, because short tapered-wedge stems perform better in Dorr type A femurs (44,45). Regarding to Optimys stem, Hochreiter et. al. (46) prospectively studied the periprosthetic BMD, which was found increased from 12.1 to 25.5% in the short stem group in the lateral part (Gruen regions 2 and region 3) and distal part (Gruen region 5) at 24 months follow up, indicating existed proximal and lateral payload, which reduced stress shielding. However, stress shielding effect does not seem to be an unknown phenomenon in short femoral components since a proximal unloading of the femur is still present.

Subsidence of femoral component has been observed in short stems, fluctuating between 0-6.5% (24). Khanuja et al. reported a mean rate of stem subsidence between 0 - 0.6% in type 4 of short stems (10). In our results, we noted a mean of 0.36 mm (0 - 1.93 mm) subsidence. In 2 out of 6 patients with major subsidence >2 mm, revision of femoral component was performed (19,47). Albers et. al. (38) related the subsidence of femoral component (0.41± 0.69 mm) to design features and rough, po-

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TABLE 5.

Radiological parameters assessed in the reviewed studies at the last follow up

STUDY	Stem type	No hips	Osteointegration	Ectopic ossification	Radiolucent line <1 mm	Osteolysis	Subsedence (mm)	Aseptic loosening	Cortical Hypertrophy	Pedestal formation	STRESS-SHIELDING Grade 1	Grade 2	Grade 3	Grade 4
(Hayashi et al., 2020)	Trilock BPS	222	N/A	N/A	101 (45.5%)	N/A	N/A	N/A	30 (13.5%)	N/A	211 (95%)		2 (0.9%)	0
(Zhen *et al.*, 2021)	Trilock BPS	42	42 (100%)	N/A	N/A	N/A	0.39 ± 0.21	N/A	18 (G3/G5)	N/A	40 (95%)	0	0	0
(Ulivi *et al.*, 2017)	Trilock BPS	163	N/A	2 (1.22%)	1 (0.61%) (G3/G4/G5)	0	0.94±0.5	N/A	9 (5.5%) (G2/G6)	10 (6.2%)	N/A	N/A	N/A	N/A
(Albers *et al.*, 2015)	Trilock BPS	123	123 (100%)	N/A	N/A	N/A	1.04 ± 0.73 1 major	1	N/A	N/A	N/A	N/A	N/A	N/A
(Slullitel *et al.*, 2020)	Trilock BPS	46	N/A	N/A	1 (2.17%) (G2/G7)	N/A	N/A	1	N/A	N/A	N/A	N/A	N/A	N/A
(Amendola *et al.*, 2017)	Trilock BPS	217	217 (100%)	2 (0.92%)	N/A	N/A	N/A	N/A	4 (2%)	13	135 (64%)	1 (0.5%)	0	0
(Tatani *et al.*, 2020)	Trilock BPS	45	45 (100%)	6 (13.3%)	0	0	0.87±0.56	0	1(2.2%) (G5)	2 (4.4%)	21 (46.6%)	5 (1.11%)	0	0
	Minima S	45	45 (100%)	3 (6.7%)	0	0	0.80±0.69	0	0	0	12 (26.67%)	1 (2.22%)	0	0
(Guo *et al.*, 2021)	Trilock BPS	104	N/A	4 (5%)	1 (1%)	0	0	0	N/A	N/A	63 (76%)	15 (5%)	6 (9%)	0
(Peng et al., 2021)	Trilock BPS	55	53 (96.4%)	0	0	0	0	0	N/A	N/A	32 (58.2%)	23 (41.8%)	0	0
(Schilcher et al., 2017)	Taperloc Microplasty	30	30 (100%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Saragaglia et al. 2020)	Taperloc Microplasty	119	N/A	N/A	0	6 (5%)	0.15±2.8	N/A	0	9 (7.5%)	N/A	N/A	N/A	N/A
(Nahas et al., 2018)	Taperloc Microplasty	196	N/A	N/A	N/A	N/A	1 major	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Gallart et al., 2019)	Taperloc Microplasty	40	N/A	N/A	1 (2.5%) (G1, G3)	0	1 major	N/A	N/A	1 (2.5%)	N/A	N/A	N/A	N/A
(Lombardi et al. 2021)	Taperloc Microplasty	92	N/A	0	0	0	0	0	0	N/A	N/A	N/A	N/A	N/A
(Hayama et al., 2020)	Taperloc Microplasty	257	257 (100%)	N/A	N/A	N/A	0	0	24(11%) (G3/G5)	N/A	177 (69%)	80 (31%)	0	0
(Uçan et al., 2021)	Taperloc Microplasty	40	N/A	N/A	N/A	N/A	1.4±0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Pogliacomi et al., 2020)	Taperloc Microplasty	60	N/A	N/A	N/A	N/A	1 major	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Uemura et al., 2021)	CentPillar GB	198	N/A	N/A	47 (27.3%) (G1, G3)	N/A	2 majors	1	N/A	N/A	62 (31.3%)	80 (40.4%)		1 (0.5%)
	CentPillar TMZF	24	N/A	N/A		N/A		N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Graceffa, 2016)	CLS Brevius	170	N/A	7 (4%)	0	0	1 major	0	4 (2.3%) (G2)	21 (12%)	N/A	N/A	N/A	N/A
(Tostain et al., 2019)	Symbios SPS	61	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A
(Drosos et al., 2020)	Minima S	61	N/A	11 (17.6%)	0	N/A	1.8±0.9	N/A	4 (6.6)	N/A	61 (100%)	N/A	N/A	N/A
(Morales De Cano et al. 2014)	GTS Biomet	81	N/A	N/A	0	0	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Thalmann et al., 2019)	Fitmore	96	N/A	N/A	21 (22%)	72 (75%)	1.93±1.72	N/A	71%	N/A	54 (56%)	N/A	N/A	N/A
(Acklin et al., 2016)	Fitmore	28	N/A	N/A	N/A	N/A	0.39 (-2.3-0.5)	1	N/A	N/A	N/A	N/A	N/A	N/A
(Maier et al., 2015)	Fitmore	100	100 (100%)	15 (19%)	20 (25%) (G1, G5, G7)	0	N/A	0	50 (63%) (G3/G5)	N/A	N/A	N/A	N/A	N/A
(Kutzner et al., 2019)	Optimys	201	N/A	2 (1%)	2(1%)	0	15.70% (<2mm)	N/A	9 (4.5%) (G3/G5)	N/A	85 (42.3%)	N/A	N/A	N/A
de Waard et al., 2021)	Optimys	34	N/A	N/A	N/A	N/A	0.16	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(Donner et al., 2019)	Optimys	102	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Major – subsidence >2mm, G – Gruen zone

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rous coating of Tri-Lock BPS, without noting correlations with Dorr type of bone and surgical approach. Fitmore femoral stem demonstrated subsidence of 1.6±1.6mm after 1 year and 1.93±1.7mm after 5 years, and a correlation was found between the amount of stem subsidence and the incidence of cortical hypertrophy (23,48).

While a previous systematic review of short stems reported 98.6% (92-100%) survival rate at a mean follow-up of 12.1 years (24), in our study the estimated combined component survivorship calculated 99% (96-100%) in an average period of 66.3 months. Uemura et. al. (20) was the outlier of follow up time, as they estimated through Kaplan–Meier analysis, that the two tapered-wedge short stems CentPillar GB and TMZF, which differentiate only in their porous coating material, have 99% overall cumulative survival rate at 15 years, which is increased in 99.5% when infection is excluded. Furthermore, we noted that the combined component survivorship was 99.4 in 69.42 months average, when the two studies of Symbios SPS were excluded, because they were the only ones reporting survival less than 98.8%, and specifically 97% and 96% by Sariali et al. (49) who reported 1 dislocation, 1 lower limb discrepancy, 2 intraoperative periprosthetic fractures and by Tostain et al. (50) who presented 4.91% revisions due to 2 periprosthetic fracture and 1 dislocation, respectively.

In this systematic review, the cumulative revision rate was calculated 0.03% (0 – 10.7%). The reported main reasons for revision were deep infection (0.2%), recurrent dislocation (0.12%), periprosthetic fracture (0.12%), aseptic loosening, major unidentified thigh pain and major subsidence. Zhang et al. (5) presented no significant difference in revision rates between short stems and conventional length stems. Australian registry presented that the ten-year cumulative revision rate for THA using a short component was 5.9% (1). Concerning complications, they are low, but not limited in modern femoral prothesis. We noted dislocation in 0.57% and deep infection in 0.39% of the included patients. Intraoperative fractures remain a problem beside the shorter stem length, however Uemura et. al. (20) suggested that the use of three-dimensional preoperative planning has led to low incidence of periprosthetic fractures.

This study, however, has certain limitations. At first, a lot of articles were excluded due to lack of data annotation. Secondly, there is a relatively small number of femoral prostheses in some of the included studies. Furthermore, even if we restricted our research to a specific category of short stems, we could not determine possible outcome differences with respect to specific design variations of each prosthesis. Next, we acknowledge that most of the included studies only presented short- term results, and, for the evaluation of the performance of femoral implants long term results are needed. Finally, as a natural limitation of every systematic review, the quality of data depends on the publications included. In this systematic review only 5 out of 36 studies were Level of Evidence I.

To sum up this systematic review demonstrated that tapered-wedge short stems with metaphyseal or meta- diaphyseal fitting, which require conventional osteotomy offer excellent short to mid-term clinical outcomes and similar revision and complication rates, equivalent to those offered by conventional length or other types of short femoral components. Excellent survival rate (99%) was recorded in 5.5 years with the use of modern short stems. Nevertheless, concerns have been raised regarding the incidence of stress shielding phenomenon and coronal stem malalignment, that need careful evaluation in well-designed high-quality randomized trials with large cohorts and long-term follow-up.

Conflict of interest
The authors declare no conflicts of interest

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READY - MADE CITATION

Tatani I., Solou K., Megas P. Short femoral stems with metaphyseal or meta-diaphyseal fitting in total hip arthroplasty: a systematic review. *Acta Orthop Trauma Hell* 2022; 73(1): 45-59.