

DIGEST AND REVIEWS

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DOI: <http://dx.doi.org/10.15674/0030-598720263110-118>**Modern rehabilitation programs after transfemoral osseointegrated prosthetic implantation with screw-fit and press-fit systems: a narrative review****O. A. Haluzynskyi¹, O. M. Linenko², M. R. Rudas³, J. Ch. Duncan⁴, F. V. Oliinyk⁴**¹ Sytenko Institute of Spine and Joint Pathology National Academy of Medical Sciences of Ukraine, Kharkiv² Bionic Technologies LLC, Kyiv, Ukraine³ «National Research Center for Radiation Medicine, Hematology and Oncology of the National Academy of Medical Sciences of Ukraine», Kyiv⁴ MN-PE «City Clinical Hospital No. 11» of the OCC, Odesa, Ukraine.

Osseointegrated prosthetic rehabilitation is a modern approach for patients after transfemoral amputation; however, screw-fit and press-fit systems differ in design, primary stability, and postoperative loading strategies. Objective. To compare contemporary rehabilitation programs after transfemoral osseointegrated prosthetic implantation using screw-fit and press-fit systems. Materials and methods. A narrative review of publications from 2001 to 2026 was conducted using PubMed, Scopus, and Web of Science. Thirty-one sources reporting on the timing and gradual increase of axial loading, use of training or interim prostheses, criteria for transition between rehabilitation stages, functional outcomes, and complications were included. Results. Screw-fit systems, particularly OPRA, are generally associated with more gradual loading after two-stage surgery. Some press-fit protocols allow earlier controlled loading and faster transition to functional activity. However, published protocols differ substantially in timing, criteria for transition between stages, and outcome assessment, and no universal rehabilitation standard has been established. Conclusions. Implant fixation type influences the pace of rehabilitation, but current evidence does not demonstrate an unequivocal long-term functional advantage of one system over another. Loading should be increased individually on the basis of clinical and functional criteria.

Остеоінтегративне протезування є сучасним методом реабілітації пацієнтів після трансфеморальної ампутації, проте screw-fit і press-fit системи відрізняються конструкцією, первинною стабільністю та підходами до післяопераційного навантаження. Мета. Порівняти сучасні програми реабілітації після трансфеморального остеointегративного протезування із screw-fit та press-fit системами. Методи. Проведено наративний огляд публікацій 2001–2026 років у PubMed, Scopus і Web of Science. До аналізу включено 31 джерело, що містило дані про строки та поетапне збільшення осьового навантаження, використання тренувальних або проміжних протезів, критерії переходу між етапами, функціональні результати й ускладнення. Результати. Для screw-fit систем, зокрема OPRA, характерне більш поступове введення навантаження після двоетапного хірургічного лікування. Окремі press-fit протоколи дозволяють раніше розпочинати контрольоване навантаження та швидше переходити до функціональної активності. Водночас опубліковані протоколи суттєво відрізняються за строками, критеріями переходу між етапами й оцінкою результатів; універсальний стандарт реабілітації не сформований. Висновки. Тип фіксації імплантата впливає на темп реабілітації, проте наявні дані не доводять безумовної переваги певної системи щодо довгострокових функціональних результатів. Збільшення навантаження має бути індивідуалізованим і ґрунтуватися на клінічних і функціональних критеріях. Ключові слова. Остеоінтегративне протезування, трансфеморальна ампутація, реабілітація, screw-fit, press-fit.

Keywords. Osseointegration; transfemoral amputation; rehabilitation; screw-fit; press-fit

Introduction

Under conditions of the full-scale war in Ukraine, the number of patients with traumatic lower-limb amputations, including transfemoral amputations, has increased substantially. Blast and firearm injuries result in complex clinical cases requiring advanced approaches to prosthetic fitting and rehabilitation. This narrative review focuses on the rehabilitation of adult patients following transfemoral osseointegrated prosthetic rehabilitation.

Traditional socket prostheses have a number of limitations, including discomfort, instability, soft-tissue complications, and restrictions in functional activity. Therefore, osseointegration prostheses are considered an alternative that provides a direct connection between the external prosthesis and the bone and may improve functional outcomes and patients' quality of life [1–2].

Modern osseointegration systems differ in the principle of primary mechanical fixation of the implant and can be broadly classified as screw-fit and press-fit systems [3–4]. In screw-fit systems, exemplified by OPRA, primary stability is achieved through threaded fixation of the implant within the bone canal; the classical protocol involves two-stage surgical treatment and gradual increases in axial loading after abutment placement [5–10]. In press-fit systems (ILP, OPL, etc.), primary stability is achieved through a tight interference fit of the implant and contact between its surface and the bone tissue. Depending on the specific system, one- or two-stage surgical protocols may be used, and in some programs controlled axial loading and prosthetic fitting are initiated earlier [11–19].

Rehabilitation after osseointegration prosthetic surgery in patients with transfemoral amputation is a staged multidisciplinary process involving gradual increases in axial loading according to the implant type and its primary stability, monitoring of pain and stoma condition, prevention of infectious complications, and restoration of muscle strength, balance, and a proper gait pattern. Objective monitoring of loading, including the use of floor scales, is important, as is individualization of the rehabilitation program according to the level of amputation, the condition of the bone and soft tissues, comorbidities, physical fitness, and functional capabilities of the patient. Rehabilitation requires coordinated interaction among the surgeon, physical and rehabilitation medicine physician, and prosthetist [2–3, 9, 17].

At the same time, despite the accumulation of clinical experience with osseointegration systems,

approaches to postoperative rehabilitation remain heterogeneous. Published programs differ in the timing of initiation and rate of progression of axial loading, the timing of introduction of training and definitive prostheses, criteria for transition between stages, and methods for monitoring functional recovery. Most protocols are system- or center-specific, while direct clinical comparisons of rehabilitation strategies following screw-fit and press-fit osseointegration remain limited. Therefore, the extent to which system design characteristics and the associated surgical protocol determine the feasibility of earlier loading and the rate of functional recovery remains unclear.

Objective: To summarize and compare current rehabilitation programs following osseointegrated prosthetic surgery using screw-fit and press-fit systems, taking into account the timing of initiation and staged progression of axial loading, timing of prosthetic fitting, criteria for transition between stages, and functional outcomes.

Materials and Methods

A narrative review of the scientific literature on the rehabilitation of adult patients following transfemoral osseointegration prosthetic surgery was conducted. Publications were searched in the electronic databases PubMed, Scopus, and Web of Science among studies published from 2001 to 2026, using the following keywords and combinations thereof: “osseointegration”, “transfemoral amputation”, “rehabilitation”, “OPRA”, “OPL”, “ILP”, “press-fit”, and “screw-fit”. The review was not designed as a systematic review; therefore, a formal PRISMA-based selection and reporting procedure and risk-of-bias assessment were not applied.

The primary target population comprised adult patients with transfemoral amputation who underwent osseointegration prosthetic surgery. Studies involving mixed cohorts of individuals with transfemoral and transtibial amputations were included if they provided data on a rehabilitation protocol, progression of axial loading, or functional outcomes relevant to transfemoral osseointegration prosthetic rehabilitation. The interval between amputation and osseointegration and the etiology of amputation were not used as separate selection criteria because these characteristics varied substantially across studies; clinical cohorts predominantly included patients with a mature residual limb and previous experience with socket prostheses.

Inclusion criteria were as follows: clinical studies of lower-limb osseointegration prosthetic surgery; studies describing screw-fit or press-fit systems; and

availability of data on at least one of the following aspects: timing of initiation and staged progression of axial loading, use of training, interim, or definitive prostheses, criteria for transition between rehabilitation stages, functional outcomes, or complications potentially affecting the rehabilitation process. Review articles, consensus documents, and recommendations containing relevant data on postoperative rehabilitation were also included. The presence of an independent control group was not required for inclusion.

Exclusion criteria were: duplicate publications; studies of upper-limb osseointegration; experimental, technical, or biomechanical studies without clinically relevant rehabilitation data; and publications that did not contain information on postoperative loading, prosthetic fitting, functional recovery, or complications related to rehabilitation. Individual publications on graded postoperative lower-limb loading that did not directly concern osseointegration prosthetic rehabilitation were used only as supplementary sources to characterize methods for objective load monitoring and were not considered in the comparison of screw-fit and press-fit systems.

The selected sources were analyzed according to study design, level of amputation, type of osseointegration system, surgical approach, timing of initiation and rate of progression of axial loading, timing of introduction of training or definitive prostheses, criteria for transition between rehabilitation stages, functional outcomes, and complications.

A total of 31 sources were included in the final analysis: 17 original clinical studies of osseointegration prosthetic surgery, 1 prospective study protocol, 11 review or consensus/recommendation publications, and 2 supplementary empirical studies. Among the 17 original clinical studies, 8 were prospective, 3 were retrospective, and 6 were other cohort, longitudinal, or observational studies.

As the study was based exclusively on the analysis of previously published data and did not involve patients or the use of their personal medical data, separate approval from a bioethics committee was not required for the review.

Results

Types of osseointegration prosthetic systems. *Screw-fit systems*

Screw-fit systems are systems in which primary implant stability is achieved through threaded fixation to the bone. The classic example is the OPRA system [5–6]. Its structural features include a threaded implant surface, gradual insertion into a prepared bone canal, controlled implant positioning, and rel-

atively uniform load distribution along the threads. Primary stability is achieved mechanically; however, complete osseointegration develops gradually. This necessitates limiting loading during the early stages and results in a longer rehabilitation period.

The surgical technique is two-stage surgery. The first stage involves placement of the intramedullary component of the implant, watertight closure of the soft tissues, and a period of osseointegration without axial loading. The second stage (after 3–6 months) involves stoma formation, abutment placement, and connection to the prosthesis. In OPRA protocols, transition between rehabilitation stages involves graded, controlled axial loading after the second surgical stage, followed by the use of a short training prosthesis and gradual transition to definitive prosthetic fitting [7–9]. Depending on the specific OPRA protocol, the short training prosthesis is introduced after the initiation of graded loading and once the patient has tolerated the preceding stage of rehabilitation [9–10].

Press-fit systems

Press-fit systems are systems in which the implant is fixed through tight contact with the inner surface of the bone canal. This group includes, in particular, ILP and OPL systems [11–14]. Structural features of these implants include the absence of threads, a porous or rough surface, fixation through an interference fit, and close contact with the cortical bone.

These systems provide high primary stability immediately after implantation, which in some protocols allows controlled axial loading to be initiated earlier and may shorten the duration of the early stages of rehabilitation. Surgery using press-fit systems may be performed using either a one- or two-stage technique, depending on the implant design and the clinical protocol adopted [12, 14–16].

Accelerated rehabilitation protocols involve early initiation of controlled axial loading followed by a more rapid transition to gait training and prosthesis use, although the specific timeframes vary depending on the system and whether a one- or two-stage surgical technique is used [9, 12, 14]. In accelerated press-fit ILP/OPL protocols, connection of a temporary or training prosthesis may be possible at an earlier stage; however, the timing depends on the specific system and surgical protocol [17–19].

Rehabilitation stages for different types of systems

Rehabilitation following osseointegration prosthetic surgery in patients with transfemoral amputation follows a common overall structure but differs substantially in the rate and intensity of loading depending on the type of implant fixation.

Screw-fit systems (OPRA system)

The stages presented below summarize data from the OPRA protocol and current reviews and recommendations [7, 9, 27] rather than reproducing the wording of a single publication. Following the second surgical stage (S2), general physical rehabilitation begins earlier, whereas axial loading through the abutment is introduced after healing of the soft tissues.

Stage 1 (first 2–4 weeks after S2) — healing and early mobilization. During the first 1–2 weeks, the primary focus is on soft-tissue healing and stoma care. From approximately the second week, gentle range-of-motion exercises of the hip joint are initiated without full voluntary muscle contraction; axial loading through the abutment is not applied at this stage [7].

Stage 2 (approximately from weeks 4–6 after S2) — graded axial loading using a short training prosthesis. This is initiated after adequate healing of the stoma and soft tissues; the load is monitored using floor scales, as shown in Fig. 1a [7, 9].

The parameters depend on the specific OPRA protocol: in the normal-speed regimen, loading begins at 20 kg and is increased by approximately 10 kg per week; in the half-speed regimen, loading begins at 10 kg and is increased by approximately 5 kg per week [7].

Loading is performed in short, controlled sessions, with assessment of pain and stoma condition. Significant pain is considered a potential indicator of overloading and a reason to adjust the loading regimen [7, 9].

In addition to monitoring the magnitude of axial loading, contemporary programs increasingly recommend using functional criteria for progression

between rehabilitation stages, including assessment of balance, walking speed, exercise tolerance, and quality-of-life measures. Functional recovery can be assessed using walking and mobility tests, including the 6-Minute Walk Test (6MWT) and Timed Up and Go (TUG), as well as assessments of walking speed, balance, and use of assistive devices [20–22].

Stage 3 — transition to a full-length prosthesis and gait training. After achieving pain-free weight-bearing at an adequate load and demonstrating appropriate control with the short training prosthesis, the patient progresses to a full-length prosthesis, gait training with assistive devices, and gradual increases in duration of prosthesis use. The specific timing varies among protocols and depends on the condition of the bone and soft tissues, load tolerance, and the patient's functional readiness [7, 9, 27].

Press-fit systems

Press-fit systems (including ILP/OPL and OGAAP protocols) are characterized by substantial variability in postoperative loading regimens. The most detailed accelerated algorithm has been described for OGAAP-2; the phases presented below specifically reflect this protocol and should not be automatically generalized to all press-fit systems [9, 12, 14].

Phase I — Early graded loading

In OGAAP-2, this phase is initiated on day 3 after surgery: static axial loading of 20 kg for 20 min twice daily, with a daily increase of 5 kg until reaching 50 kg or 50 % of body weight [12].

Phase II — Rehabilitation prosthesis

After reaching the recommended loading level, a lightweight rehabilitation prosthesis with a stable knee module is fitted; exercises targeting trunk muscles and balance are continued, along with gait training in parallel bars [12].

Phase III — Transition to the definitive prosthesis

After safe mobilization with the rehabilitation prosthesis, the patient transitions to a definitive prosthesis and daily loading. In OGAAP-2, the early postoperative rehabilitation phase is planned to be completed within approximately 3–6 weeks, after which gait training and gradual reduction in the use of assistive devices continue [12].

Thus, some accelerated press-fit protocols allow controlled axial loading to be initiated earlier; however, the timing depends on the specific system, the use of a one- or two-stage surgical approach, and individual load tolerance [9, 12, 14, 15].

Criteria for Transition Between Rehabilitation Stages

Transition between rehabilitation stages should not be determined solely by chronological time points.



Figure. Photographs of controlled axial loading: a) use of a short training prosthesis (screw-fit implant) with the use of floor scales; b) patient at the end of the rehabilitation process with a press-fit implant

Contemporary protocols recommend considering tolerance of the preceding loading level, pain intensity [9, 19] during and after training, the condition of the stoma and surrounding soft tissues [28], absence of signs of infection or implant instability, and the patient's functional status [9, 17]. In the presence

of an adverse clinical response, further increases in loading should be suspended or modified.

Despite common rehabilitation principles, published protocols demonstrate substantial differences in the timing of loading initiation, rates of load progression, and timing of transition to definitive prosthetic fitting. The main differences between rehabil-

Table 1

Objective measures of functional recovery used following transfemoral osseointegrated prosthetic treatment

Outcome domain	Measure used	Post-osseointegration findings
Walking speed	10MWT, walking speed at a self-selected pace	Improvement has been reported in civilian OPRA cohorts; early changes may be heterogeneous [22–23]
6MWT	6MWT, occasionally the 2MWT in consensus recommendations	Performance may improve in prospective cohorts; in some small samples, changes do not reach statistical significance [24–25]
Timed Up and Go (TUG)	TUG as a basic test of mobility and physical performance	Often improves by 12 months; changes may be minimal in some high-functioning cohorts [21,24]
Balance / function	4SST, FSST, CHAMP, AMP/BAMP	These assessments are used less frequently; however, direct evidence indicates lower oxygen consumption with osseointegration compared with socket-suspended prosthetic use [26]
Energy expenditure	Oxygen consumption / oxygen consumption during walking	These assessments are used less frequently; however, direct evidence indicates lower oxygen consumption with osseointegration compared with socket-suspended prosthetic use [26]

Table 2

Comparative characteristics of rehabilitation protocols following osseointegrative prosthetic reconstruction with screw-fit and press-fit systems

Parameter	Screw-fit (OPRA)	Press-fit (ILP, OPL, OGAAP)
Surgical approach	Predominantly two-stage [1, 7]	One- or two-stage, depending on the system and protocol [12, 14–16]
Mechanism of primary stability	Threaded fixation [1, 5]	Interference (press-fit) fixation [3, 11, 13, 19]
Initiation of graded axial loading	Delayed; initiated after the second surgical stage according to the OPRA protocol [7, 9, 27]	Earlier initiation of controlled loading; timing depends on the specific system and surgical protocol [9, 12, 14]
Rate of load progression	Depends on the OPRA protocol variant: approximately +10 kg/week with the normal-speed protocol and +5 kg/week with the half-speed protocol [7]	Varies according to the protocol; in OGAAP-2, approximately +5 kg/day up to 50 kg or 50% of body weight [9, 12, 14]
Fitting of a training or interim prosthesis	In the classic OPRA protocol, a short training prosthesis is fitted approximately 4–6 weeks after the second stage, provided that the stoma has healed [7, 9]	Timing varies; in OGAAP-2, the rehabilitation prosthesis is fitted after achieving 50 kg or 50% of body weight [12]
Achievement of full axial loading	Approximately 10–14 weeks after the second surgical stage [7, 9, 27]	Approximately 6–8 weeks in some accelerated protocols [9, 12, 14, 27]
Achievement of independent walking	Approximately 4–6 months, depending on the protocol and clinical status [7, 9, 27]	Approximately 2–3 months in some OGAAP/press-fit protocols; timing varies substantially according to the system and criteria for functional independence [9, 12, 14–16]
Primary rehabilitation principle	Protection of the osseointegration process and gradual, controlled progression of loading	Early functional activation with controlled progression of loading

Note. The timeframes presented are approximate and should not be regarded as universal criteria for progression between rehabilitation stages. They depend on implant design, the use of a one- or two-stage surgical approach, primary stability, the condition of the bone and soft tissues, load tolerance, and the patient's functional status [9, 16, 17, 27].

itation programs following the use of screw-fit and press-fit systems are summarized in Table 2.

Discussion

K. Hagberg and R. Brånemark [2] directly associated the success of OPRA with graded rehabilitation following two-stage surgery; they also noted that most failures occurred before protocol standardization and considered the introduction of graded rehabilitation critically important for achieving better outcomes. This supports the view that the longer period of gradual loading in OPRA was not incidental but rather an integral component of the system, associated with the two-stage surgical approach and the need to safely complete osseointegration [3, 11, 12].

In press-fit protocols, M. Al Muderis et al. initiated rehabilitation during the inpatient period, with early axial loading and mobilization in parallel bars, while definitive prosthetic fitting was often performed at approximately 14 days [15]. Certain press-fit designs, owing to their high primary mechanical stability, allow protocols involving earlier controlled loading and shortening the interval between stages to 4–6 weeks; in OGAAP-1 and OGAAP-2, this was described as an approach enabling more rapid progression to walking and completion of postoperative rehabilitation within approximately 3–6 weeks [12, 14].

Published rehabilitation protocols remain heterogeneous with regard to the timing of loading initiation and rates of progression, timing of prosthesis introduction, and criteria for transition between stages. Most are center- or system-specific, and direct comparative studies remain limited; therefore, a universal rehabilitation standard has not yet been established [9, 26, 27].

The use of screw-fit systems, particularly OPRA, entails a more conservative approach to postoperative rehabilitation. This is attributable to the characteristics of implant–bone interaction and the osseointegration process, which requires a longer period for formation of a stable implant–bone interface. Accordingly, loading is introduced gradually and under strict monitoring, thereby minimizing the risk of implant micromotion and potential disruption of the osseointegration process [7, 9, 27].

In contrast, press-fit systems (particularly ILP and OPL) provide greater primary mechanical stability through tight fitting of the implant within the bone canal. This allows graded axial loading to be initiated earlier and facilitates a more rapid transition to functional activity. At the same time, this strategy requires careful clinical monitoring, as subjective im-

provement in the patient's condition may lead to premature overloading of the implant [11–13].

An important component of contemporary rehabilitation protocols is the use of objective methods for monitoring loading, particularly floor scales. Instrumented systems and biofeedback methods have also been described for objectively quantifying graded loading during postoperative lower-limb rehabilitation [30, 31]. Such technologies may improve the accuracy of partial-load monitoring; however, their specific use following osseointegration prosthetic surgery requires further investigation. Controlled progression of loading remains an important component of safe functional adaptation regardless of the type of implant [2, 3].

The role of training prostheses in the recovery process also warrants particular attention. The available literature describes training or temporary prostheses as an intermediate step between isolated graded loading and independent walking, and this principle is applied in OPRA, press-fit, and accelerated protocols. Their use enables a gradual transition from isolated graded loading to full gait, facilitates the development of an appropriate movement pattern, and improves neuromuscular coordination, although direct comparative evidence of their superiority remains limited [9]. This is particularly important in patients following prolonged immobilization or with a high level of amputation.

The literature analyzed indicates that earlier achievement of full axial loading with certain press-fit protocols may shorten the time to transition to functional activity. However, more rapid progression through the early stages of rehabilitation should not automatically be equated with better long-term functional outcomes.

At the same time, the choice of rehabilitation strategy cannot be based solely on the type of implant. Individual patient characteristics, including bone quality, physical fitness, comorbidities, and motivation for rehabilitation, play an important role. Therefore, a multidisciplinary approach involving the surgeon, rehabilitation physician, and prosthetist is optimal.

Complications and Considerations

Published clinical series of press-fit osseointegration prosthetic surgery demonstrate generally favorable functional outcomes; however, infectious and other complications remain important factors when determining the rate of postoperative rehabilitation. In a prospective two-center study, most infections were mild soft-tissue infections and were successfully managed conservatively [11]. In a two-stage post-traumatic series, infectious episodes

were controlled without implant removal, while in the OGAAP-1 study, all patients were using osseointegrated prostheses at the end of follow-up, although adverse events remained common [14, 15].

More recent comparative data on one- and two-stage procedures suggest possible differences in the pattern of infectious complications, whereas the duration of rehabilitation may not differ substantially between the groups [16]. Therefore, earlier mobilization in accelerated press-fit protocols should be undertaken under careful clinical monitoring and cannot automatically be considered a guarantee of better long-term functional outcomes [9, 16].

Limitations

This narrative review is based on studies that differ in design, patient characteristics, implant types, and rehabilitation protocols. Among the included primary clinical studies, no randomized or direct head-to-head studies were identified that compared rehabilitation outcomes after screw-fit and press-fit osseointegration in parallel patient groups. Therefore, the comparison of the systems is based primarily on an indirect analysis of system- and center-specific cohorts, which limits the ability to quantitatively compare the effectiveness of individual rehabilitation programs.

Thus, an analysis of the current literature indicates that the main differences between screw-fit and press-fit systems concern the timing of initiation of graded weight-bearing, the rate of functional recovery, and the duration of rehabilitation, whereas the general principles of postoperative recovery remain similar.

Conclusions

The type of implant fixation is one of the key factors influencing the structure, intensity, and duration of the rehabilitation program following transfemoral osseointegrated prosthetic treatment.

The use of screw-fit systems, particularly OPRA, involves a more gradual introduction of axial loading aimed at providing conditions for safe osseointegration and functional adaptation.

According to the analyzed studies, press-fit systems (particularly ILP and OPL) are associated with the possibility of earlier initiation of controlled axial loading and faster achievement of full weight-bearing within certain accelerated protocols. However, the available evidence does not allow a definitive conclusion regarding their superiority in terms of overall rehabilitation duration or long-term functional outcomes.

The use of objective methods for monitoring loading and an individualized approach to rehabilitation may contribute to achieving optimal functional outcomes regardless of the implant type.

Conflict of interest. The authors declare no conflict of interest.

Future research. A promising direction is the development of standardized, evidence-based recommendations for rehabilitation following osseointegrated prosthetic treatment, taking into account the type of implant and individual patient characteristics.

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Authors' contributions. O. A. Haluzynskiy — study concept and design, methodology, analysis and interpretation of results, preparation of the initial manuscript; the remaining co-authors — clinical work and data collection; all authors participated in the discussion of the results, critical revision of the manuscript, and approval of its final version.

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MODERN REHABILITATION PROGRAMS AFTER TRANSFEMORAL OSSEOINTEGRATED PROSTHETIC IMPLANTATION WITH SCREW-FIT AND PRESS-FIT SYSTEMS: A NARRATIVE REVIEW

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