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Tissue-sparing surgery: 25 years' experience with femoral neck preserving hip arthroplasty

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Abstract Tissue-sparing surgery is a surgical strategy that aims to preserve, as much as possible, both bone and soft tissue, in order to minimize the invasiveness of the operation and the overall treatment aggression. This is achieved, in the field of hip replacement surgery, by conservation of the femoral neck through the use of "mini-prostheses" such as the Biodynamic and later the CFP. In this paper, we illustrate the biomechanical characteristics and structure of the CFP prosthesis and briefly describe our 25-year experience in conserving the femoral neck during hip replacement surgery. In particular, we report the results of 943 implants, demonstrating a high percentage of excellent results and good clinicoradiographic results (97%) with a survival rate of almost 100%.

Key words Tissue-sparing surgery • Femoral neck preserving • Arthroplasty • CFP hip prostheses

Introduction

Endoprosthetic hip replacement has to be assessed in terms of preservation, i.e. restoration of the normal anatomic geometry. Restoration of anatomical geometry not only ensures optimal gait but has also a direct effect on maintaining vital valgus and varus muscle forces, acting as re-establishing force against the occurring load and thus balancing the hip joint. Observation of the CCD angle for prosthetic hip replacement is therefore crucial (Fig. 1).

Implantation of a hip prosthesis stem inevitably causes unphysiological loading of the femur. The acetabular region is affected as well after insertion of an acetabular cup. Depending on the unphysiologic load patterns, these forces lead to bone reactions, putting the stability of the artificial hip joint at risk. As a consequence, the goal must be to reduce inevitable unphysiological loading of the bone caused by implantation of a prosthesis as good as possible, or, in other words, to stimulate and thus preserve the stability of the bone structures in conjunction with a well fixed prosthesis [1].

According to Wolff's law, compression forces stimulate bone formation (Fig. 2). In conjunction with compression forces occurring in the hip joint, tension and torsion forces are released following the flow of forces from the ilium to the femur: tension and torsion forces are primarily effective in the proximal femur (Fig. 3) [2]. In accordance with these forces, the natural trabecular pattern of the bone and the trabecular orientation provide support against the natural functional loading, thus creating the necessary functional stability of the individual bone areas. In the proximal femur, the femoral neck and the adjoining medial aspect of the femur in the calcar region show the

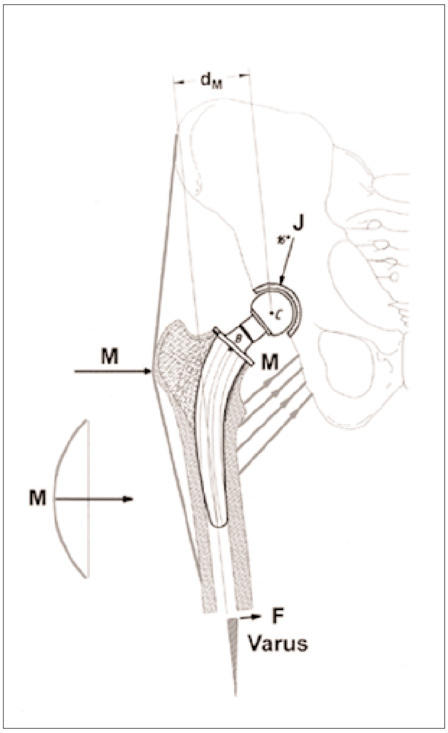

Fig. 1 Force against the occuring load, balancing the hip joint

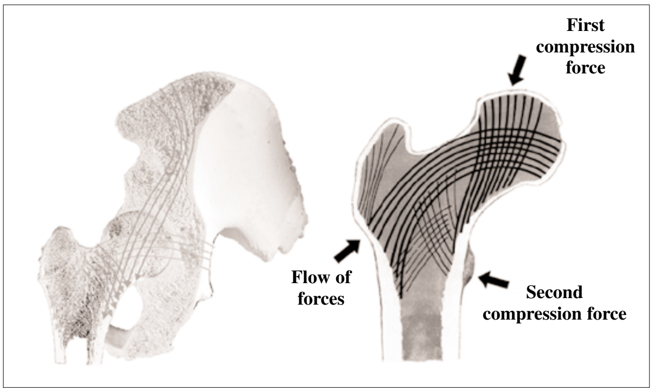

Fig. 2 Trabecular pattern of the bone and flow of forces in the proximal femur

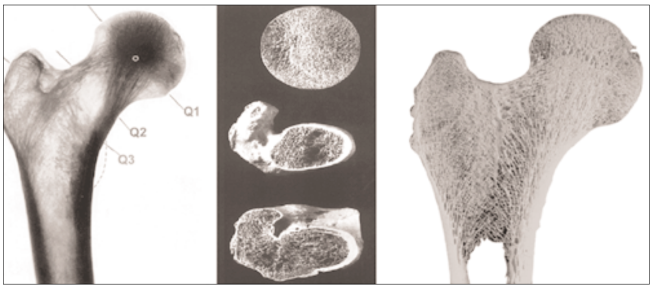

Fig. 3 The femoral neck shows the strongest bone structures in the whole femur

strongest bone structures with a high load capacity for the support of prosthesis stems [3]. Because of the angular position of the femoral neck, its preservation protects the prosthesis stem effectively against torsion forces [4].

With the femoral neck intact, the branchouts of the femoral circumflex arteries are preserved, maintaining the blood supply and nutrition of the proximal femur region and thus supporting the preservation of these load-bearing bone structures (Fig. 4).

Based on these anatomical and physiological conditions, Pipino in 1979 presented the femoral neck-preserving Biodynamic hip prosthesis for cementless fixation (Fig. 5).

The Biodynamic hip prosthesis, implanted from 1983, showed a convincing follow-up performance and therefore came up to the expectations set into this prosthesis system featuring a biodynamic harmony in the load transfer to the bone. The results are excellent also in comparison with those of other contemporary prosthetic designs [5–8].

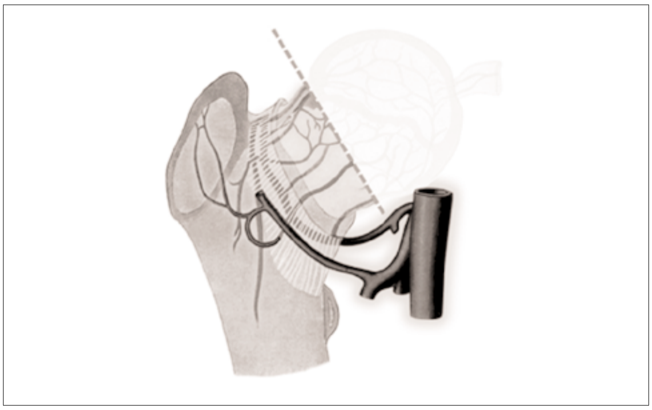

Fig. 4 When the femoral neck is left intact, the femoral circumflexes are preserved

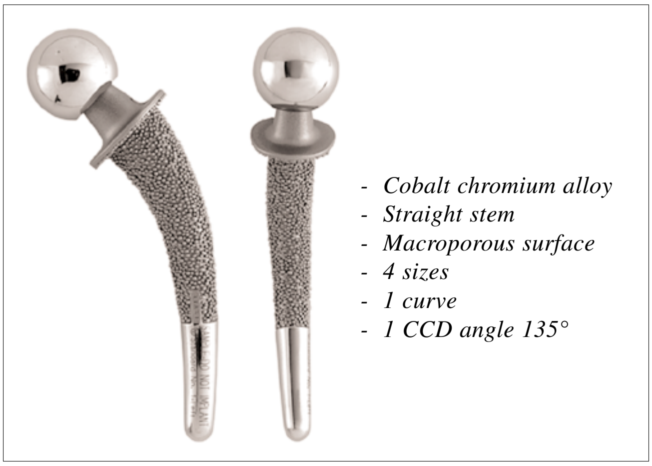

Fig. 5 Biodynamic hip stem

CFP hip prosthesis stem

The neck-preserving hip prosthesis designed by Pipino in 1979 was implanted until it was replaced by the modified CFP hip prosthesis in 1996.

The CFP prosthesis stem is made of titanium alloy, a material better suited for cementless fixation than cobalt-chromium alloy. The left and right stem versions with built-in anatomical anteversion are adapted to the normal anatomy (Fig. 6).

Left and right stems are available in 6 sizes, each with 117° and 126° CCD angles. There are 2 stem curvatures (A and B) to allow a smooth fit on the medial bone structures of the femoral neck and the adjoining calcar region (Fig. 7).

The oval-shaped CFP stem features bilateral longitudinal ribs to increase the surface contact with bone for secure implant anchorage and to oppose torsion forces on the prosthesis stem (Fig. 8).

When indicated, the prosthesis neck-plate can be removed to impact cancellous bone chips. In case of a revision, the removable neck plate allows access to the prosthesis stem for easier stem removal (Fig. 9).

To promote osseointegration, the CFP stem has a 70 µm microporous surface with the exception of the short distal portion. In addition, the microporous surface is provided with a special 20 µm hydroxyapatite (calcium phosphate) coating which does not seal the surface but keeps the porous structure intact (Fig. 10).

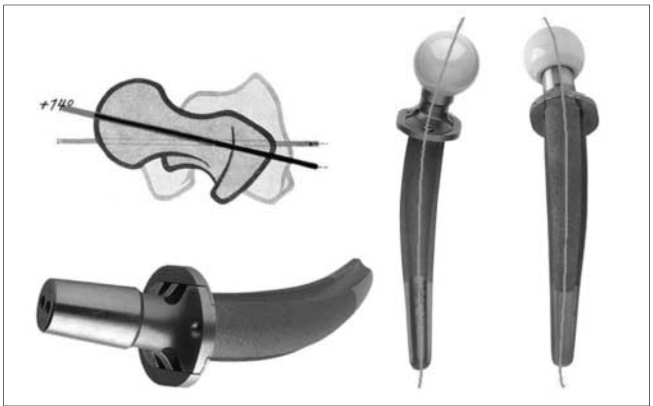

Fig. 6 Left and right stems with built-in anatomical anteversion are adapted to the normal anatomy

Fig. 7 CFP stem

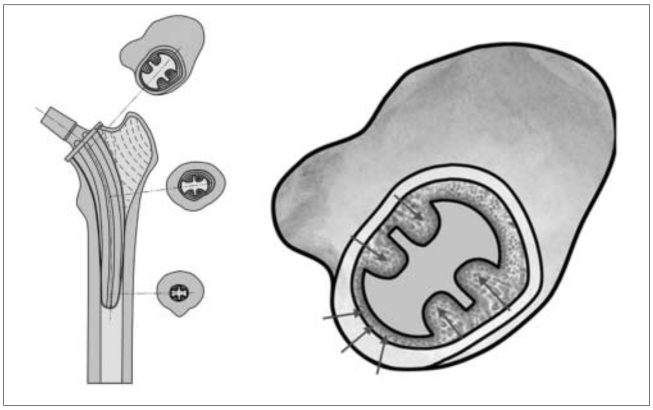

Fig. 8 Bilateral longitudinal ribs increase the surface contact with bone

Fig. 9 The prosthesis neck-plate can be removed

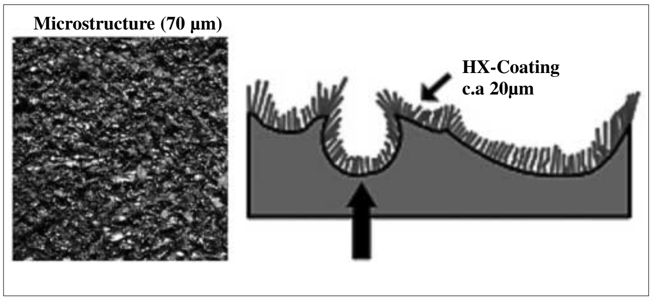

Fig. 10 The microporous surface is provided with a special 20 µm hydroxyapatite

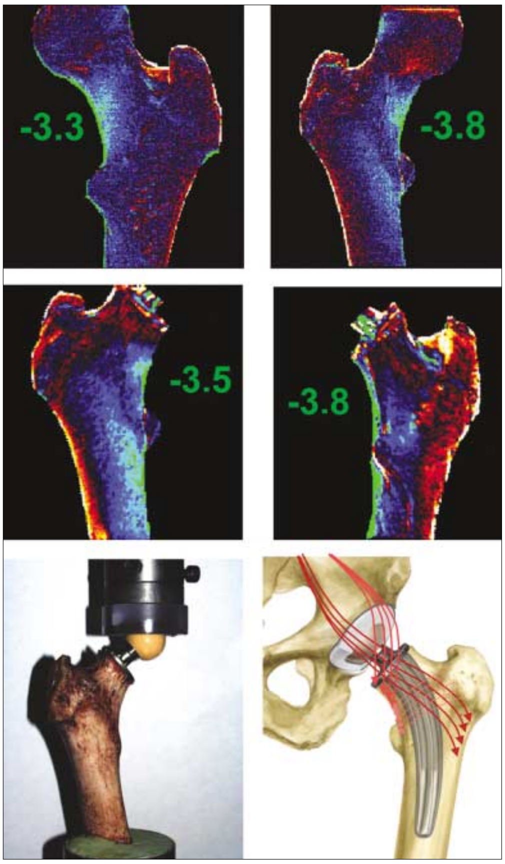

Fig. 11 Comparative photoelastic studies of femurs with and without implanted CFP systems

The prosthesis stem is impacted without sacrificing any bone stock. After resection of the femoral head, the distal stem size is determined using a curved probe. Appropriate bone compressors prepare the implant bed. The compressors without ribs precompress the cancellous bone. When impacting the CFP stem, the primarily stable pressfit seating of the stem is secured by the longitudinal ribs on the prosthesis stem which bite into the cancellous bone, achieving an implant-bone contact of up to 87%.

A precondition for a stable press-fit seating, however, is a sufficiently vital and stable quality of the cancellous bone. Comparative photoelastic studies of femurs with and without implanted CFP stems showed a harmonic correlation, thus supporting the biodynamic efficiency of the CFP prosthesis stem with regard to maintenance and load capacity of natural physiological bone structures (Fig. 11).

Because of this positive experience, a cemented version of the collum femoris preserving (CFP) prosthesis is implanted in patients whose bone quality does not allow cementless fixation. While identical in shape with the cementless CFP stem, the cemented CFP version does not feature longitudinal ribs.

TOP acetabular cup

The metal TOP casings are made of titanium alloy. Corresponding to the normal anatomical acetabular geometry, the outer shell is hemispheric (Fig. 12).

TOP acetabular cups are designed for press-fit fixation. To ensure a primarily stable anchorage in the acetabulum, the outside shell has a circular segmental row of teeth at the equator. A peep hole at the cup's pole which can be locked with a titanium screw allows to verify the close contact to the acetabular floor. When additional fixation is required, anchoring screws can be applied after removal of the integrated locking plugs in the shell.

Fig. 12 The top cup is hemispheric with biequatorial dissociation

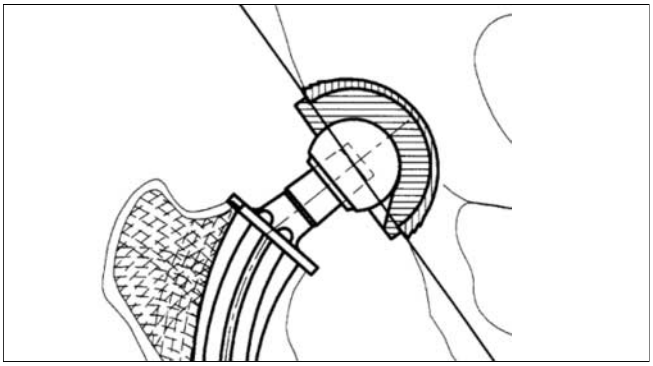

Fig. 13 Polyethylene top insert biequatorial

Fig. 14 The top insert can be placed in one of the five circular positions

Fig. 15 A mediocaudal recess in the shell provides a wider range of motion

To support osseointegration, the outer TOP shell has a 70 µm microporous surface with additional HX-coating (calcium phosphate), as does the CFP hip stem. The polyethylene TOP inserts are stabilized inside the shell by a special snap-lock mechanism. Femoral head dislocation is reduced due to the inside cup design featuring a cranial cup rim reaching over 180° (Fig. 13).

Inside the metal casing, the polyethylene TOP inserts can be placed in one of five circular positions (Fig. 14) [9].

A mediocaudal recess in the shell protects the psoas tendon and the femoral nerve. Compared to acetabular cups with a circular rim, the TOP cup provides a wider range of motion of the femoral component inside the acetabular cup (Fig. 15).

Clinical results

We report only the data of 943 implants, demonstrating a high percentage of excellent clinical results and good radiograph outcome [8].

Biodynamic Total Hip Prosthesis

Biodynamic's case report: 498 hips

Years	Kind of implants	N°	Published	Clinical results
1983-1987	All madreporic surfacing stem	56	Journal of Orthopaedics and Traumatology Vol 1 – 1: 31-39 - 2000	F.Up: 13-17 ys Controlled 44 37% excellent 45% good 14% fair 4% poor
1986-1990	Madreporic surfacing 2/3 proximal , 1/3 distal smooth stem	200	Italian Journal Orthopaedics and Traumatology Vol.19 n.1-1993	F.Up: 1-5 ys 68% excellent 22% good 9% fair 1% poor
1991-1996	Madreporic surfacing 2/3 proximal, 1/3 distal polished stem	242	unpublished	F.Up 6-11 ys 60% excellent 30%good 8% fair 2% poor Sopravvivenza 98%

Complete case report of the Biodymanic stem from 1983 to 1996: 498 implants

CFP Total Hip Prosthesis

Case report
04/1997 - 12/2005

Treatment group	418
Follow-up group	371
Implants	445
Follow-up implants	393

Clinical Results
(HARRIS HIP SCORE)

FOLLOW-UP
(December 2005)

N° Implants 393	Hip Score	Clinical results
358 (91%)	90 – 100	Excellent
23 (6%)	80 – 89	Good
8 (2%)	70 - 79	Fair
4 (1%)	< 70	Poor

	Treatment group	Follow-up group
Age, years (mean value)	60	58
Male, n (%)	62	60
Diagnosis (%)		
Coxarthrosis	82	80
Necrosis of the femoral head	8	8
Dysplasia	6	8
Other	4	4

Radiographic outcome

Good integration	99%
Loosening	1%

Bone remodeling

Good	90%
Fair •Neck round-off •Demarcation lines •Not progressive radiolucency	10%

Radiographs

Fig. 16 Preoperative radiographs of right hip

Fig. 17 Postoperative radiographs

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