

CURRENT STATE OF CEMENT FIXATION IN THR

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The author surveys important landmarks in the development of total hip arthroplasty, with an accent on implant fixation using acrylic cement. He explains why he personally opted for hybrid prostheses, combining a cemented stem and a cementless socket, in patients over sixty years. Excellent cementless, sockets have been available for a long time ; on the femoral side, the first steps were difficult, but several cementless, stems were subsequently developed, which provided excellent long term results. This historical evolution resulted in a very uneven use of cemented versus cementless stems from one country to another in Europe. Cemented implants have enjoyed a renewed popularity over the past few years as a result of several factors, including economical factors. The author discusses the conditions for optimal fixation of a cemented stem ; these conditions are not always met satisfactorily, as a number of surgeons obviously stick to a crude cementing technique. The author describes the role of the stem geometry and surface finish, as well as the possible influence of a centralizer ; he explains why, based on a correct analysis of the available data, discredit has been unduly cast on cemented stems made of titanium alloy. He insists on one important although often disregarded factor : the specific type of cement used, as better results have clearly been achieved with certain cements than with others. He insists on the necessity to take into account all the elements involved, in order to avoid making erroneous conclusions. He also insists on one very important variable, the quality of the surgical technique. Total hip arthroplasty is likely to make further progress in the future, although we are likely now in the asymptotic portion of an ascending curve. Further improvement in clinical results will result from improvement of currently existing systems and optimization of surgi-

cal technique, rather than from the continuous designing of new implants.

Keywords : total hip arthroplasty ; cement fixation.

Mots-clés : prothèse totale de hanche ; fixation au ciment.

The first use of orthodontic polymethylmethacrylate (PMMA) cement by John Charnley in 1959 to anchor total hip replacement (THR) components in the bone revolutionized hip arthroplasty (9). Many orthopedic surgeons, however, were skeptical about PMMA, some completely refusing to use it — at least at the beginning of the sixties. At that time, however, there were already non-cemented THRs on the market, and efforts to develop methods of fixing the components firmly in the osseous bed without cement were encouraging and continuously pursued. The first non-cemented THRs in Europe were the prostheses of Peter Ring/UK (42), Heinz Mittelmeier/Germany (31) and the K. M. Sivash/Moskva-Russia (46). The predecessors of THR, the hemiarthroplasties of the Judet brothers, Moore etc. were also obviously fixed without cement . Thus, further developments in cemented implant fixation, especially in Europe, should not be considered uni-dimensionally.

Progress in medicine is not linear and harmonious ; it alternates between success and failure.

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Despite globalization of medicine, acceptance of different treatment methods varies from one country to another. Even within the various countries, different methods are used. Furthermore, innovative ideas are created by innovative individuals. The degree of acceptance also differs from one individual to another. A review about the use of bone cement in THR, therefore, is very much influenced by personal experience and personal preferences. The development of implant anchorage is a road paved with failures and successes, both in cemented and non-cemented fixation.

The primary author's first contact with bone cement was in combination with a McKee-Farrar prosthesis (30), which was inserted at our Orthopedic Department in Basel in 1966. From 1967 onwards, we used the Charnley-Müller curved stem with a cemented polyethylene cup. The high incidence of fractured femoral components was overcome by the change from cast to forged CoNiCrMo-alloy (Protasul-10) and has since become a matter of the past. In 1977, Maurice E. Müller introduced the cemented Straight Stem manufactured from Protasul-10. Based on our experience with the non-cemented, non-coated all-polyethylene RM cups, in which we had observed massive wear and no osseointegration, we decided to develop a Press-Fit Cup in collaboration with Sulzer Orthopedics, Winterthur. The Press-Fit Cup has a porous coating made of a mesh of 4 orderly orientated layers of c.p. titanium (SULMESH®), which is directly fixed to the polyethylene resin (monobloc acetabular cup) (32-34). In the mid-eighties, non-cemented, porous-coated cups with and without metal-backing, with press-fit (oversize) or screw fixation became popular and yielded, even in the longer term, excellent results. During the last 20 years, we have not used fully cemented acetabular cups at our institution, except for tumor cases. The same experience with non-cemented, porous-coated cups and cemented stems inserted with improved, so-called modern, cementing technique (3) was made in the US during the early eighties. Thus, the "Hybrid THR", i.e. the combination of a cemented stem with a non-cemented cup, became the standard procedure for patients older than 50 to 60 years for a great number of

orthopedic surgeons (38). The rationale for a hybrid THR was based on the experience that with modern cementing techniques, the results on the stem side could be greatly improved, whereas on the acetabular side, clinical results with non-cemented cup designs were more promising than those of their cemented counterparts, despite modern cementing techniques. The hybrid THR also became the logical consequence after several authors demonstrated that the main problem of cemented THR was aseptic loosening of the cup (7, 35). Our own follow-up of 2,669 cemented Charnley-Müller hip arthroplasties and 141 revision arthroplasties performed between November 1970 and February 1982 revealed that the incidence of femoral stem loosening increased linearly. Revisions for acetabular loosening, however, were rare until the 6th to 8th post-operative year, but increased exponentially thereafter (35). The dominance of hybrid THR across Europe shows that both cemented stems and non-cemented cups are inserted in about 60% of the cases.

As a non-cemented stem, the PCA stem (Howmedica, Rutherford, USA) was widely used, both in the US and in Europe — especially for younger patients — but revealed disappointing results, with thigh pain and aseptic loosening in an unacceptably high number of patients. The use of non-cemented stems, therefore, declined drastically. In 1992, for example, only 4% of the stems implanted at our institution were non-cemented.

On the other hand, other non-cemented femoral stems such as the CLS prosthesis of Spotorno, the Zweymüller stem, the Bicontact etc., which were developed during the eighties, became very successful, as we know today. The main reasons for the superiority of these stems over the PCA prosthesis were their conical design allowing the stem to function according to a press-fit concept, and a more "osteophilic" implant surface (roughness, titanium, sharp edges). An industrial marketing analysis of 1998 has shown that, within the European countries, there are great national variations from 91% cemented THRs in the UK to 10% cemented and 90% non-cemented hip arthroplasties in Austria (fig. 1).

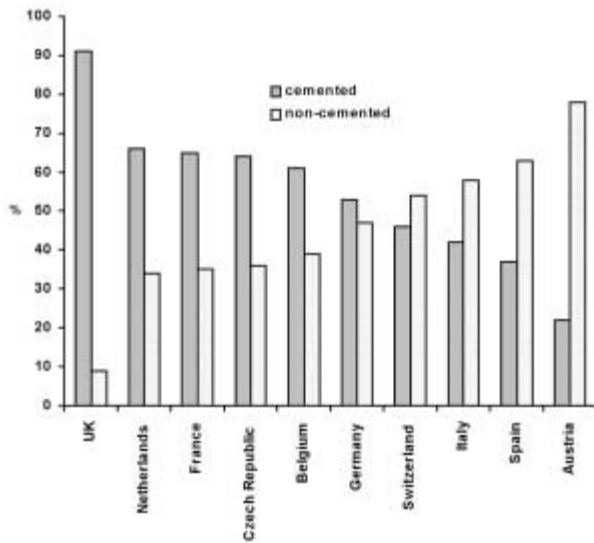


Fig. 1. — Cemented and non-cemented femoral stems used in primary THR in various European countries.

As mentioned above, from 1978 onward, and throughout the eighties, we used the Müller Straight Stem as our standard cemented femoral component. In a follow-up study, this stem revealed excellent clinical results with a 10-year survival rate of 97% (55). The xrays, however, showed subsidence of the stems of 2 to 5 mm in 11% of the cases. Subsidence, i.e. migration of an implant, was, at that time, considered to be equivalent to definitive loosening. Thus, it was a matter of concern, although there was no correlation with pain. Today, subsidence of tapered stems such as the Müller Straight Stem, the Exeter or the MS-30 Stem is no longer considered to be a sign of impending or definitive loosening. With subsidence through axial loading, the stability of a tapered stem increases — which explains the good survivorship of these types of stem.

Since with the Müller Straight Stem the largest possible size stem is always used for every femur, a press-fit is achieved between the medial and lateral wall of the femur. Thus, the prosthesis stem has a direct metal/bone contact at the medial and lateral aspect of the medullary canal and the cement/stem interface — as part of the “effective joint space” (44) — is widely opened.

As the main load is transmitted through the medial and lateral cortical walls, stress on the

cement is reduced. The cement acts more as a filler material rather than as a force transmitter. The Straight Stem, therefore, could be called in itself a “hybrid stem”. It is interesting to note that in the designing surgeon’s (M. E. Müller, Berne) own department, the Straight Stem was in a few instances fixed without cement (40). The stem was slightly modified by adding fenestrations in its proximal portion, meant to enable bony bridges to grow across the implant. The clinical trial, however, ended with an unacceptably high rate of unsatisfactory results. The same was experienced by Stockley *et al.* on 24 hips in 21 patients with a revision rate of 21% (47). The Müller Straight Stem Prosthesis has been copied many times. A non-cemented titanium version with proximal porous coating (Taperloc, Biomet), however, has been reported to yield satisfactory clinical results (43).

Failures in cementing are related to insufficient medial support, insufficient cement/bone interdigitation, insufficient cement mantle with metal/bone contact and, finally, inadequate positioning of the stem. Because of the direct metal/bone contact of the Straight Stem, particles find their way from the cement/stem interface to the bone/cement interface, resulting in the development of osteolyses and subsequent aseptic loosening. As soon as debonding and micromotion between the stem and the surrounding cement has occurred, the production of wear particles starts. Particles — independent of where they are generated and what they consist of — migrate from the cement/stem interface to the cement/bone interface and into the joint space and vice versa. Examining autopsy specimens of cemented hip arthroplasties (mostly Müller-Charnley type), Gächter found in 11 out of 63 cases, i.e. in 17.5% only, an intact cement mantle (13). In cases where corrosion products — for example originating from broken cerclage wires of the greater trochanter — entered into the articulation area, the black-stained corrosion products were distributed over the whole stem/cement interface. In animal experiments with polyethylene-carbon acetabular sockets, Gächter was able to show that the abrasion products infiltrated the calcar region from the capsule. Vidovski *et al.* (1998) found polyethylene particles at the tip of a non-cemented

prosthesis stem (52). A 15-year follow-up of the Müller Straight Stem, manufactured of CoCrMoNi (Protasul-10) (41), showed an increase in the number of loosening. The survival rate dropped to 86% after that time period. Subsidence of the stem was observed in 69% of the cases after 15 years. The main reason for the increase of the revision rate was the massive amount of polyethylene debris originating from the outer surface of the now discontinued non-cemented, non-coated all-polyethylene cups.

There is still a steadily growing market for bone cement. During the last couple of years, a tendency to return to cemented THRs has been observed. This trend can be attributed to : 1. Non-cemented implants which experienced problems with regard to product failure and which have required revision surgery as often, or, sometimes more often, than cemented implants, especially in modular systems, 2. The trend towards greater cost consciousness starting in the mid-nineties, which put enormous economical pressure on many hospitals, and led to a shift towards the less costly cemented implants.

The importance of an optimal cement mantle

Various studies have shown that an optimal cement mantle is among the most important factors for the longevity of a cemented prosthesis stem. According to finite element studies (21, 25), cadaver retrievals (23), radiological studies (10) and clinical observations (3, 38), the optimal cement mantle is asymmetric and not harmonious, prevents metal/bone contact, is 1 to 3 mm thick in Gruen zones 2 to 6, 4 to 7 mm thick in zones 1 and 7, and the metallic stem achieves a canal fill of > 50%. There is no longer any doubt that the cementing technique plays a key role in the quality of the cement mantle and that modern techniques have led to a significant improvement of the results of cemented THR (15, 38). In view of this, it is disappointing that, according to surveys in Germany and Great Britain, the number of orthopedic surgeons using modern cementing techniques is very low : slightly over 10% in Germany (6) and 35-40% in the United Kingdom for hemiarthroplasties (45). However, it must be admitted that the definition of

what is called “modern cementing technique” is widely discussed and there is no “*unité de doctrine*”. General agreement exists in relation to the benefit of lavage and drying of the medullary canal and the use of a plug with the introduction of the cement under pressure (pressurization). Nevertheless, pressurization was made in Germany only in 63% of the cases (6).

However, an optimal cement mantle depends not only on the quality of the cement and the cementing technique, but also to a high degree on the prosthesis design. In cooperation with L. Spotorno and Sulzer Orthopedics, the cemented MS-30 stem was developed (36) — based upon good clinical, but less convincing radiological experience with the Müller Straight Stem (55). The aim, to achieve an optimal cement mantle through the prosthetic design, was realized in the MS-30 with the following characteristics : 1. three-dimensionally tapered stem, thus generating a press-fit in cement fixation, 2. undersized stem (planning !), providing the necessary space for an optimal, complete cement mantle, 3. distal centralizing system, 4. rounded edges to equalize stress distribution and to minimize peak stresses in the cement mantle, 5. additional rotational stability (lateral flanges and a high neck resection).

Because of the results published by the Exeter group, and the ongoing discussion as to whether the stem surface should be polished or matte, a randomized prospective study was started in 1994 with the only difference between the two groups being the stem surface condition. Both, the matte (Ra 1.4 μm) and the polished version (Ra 0.02 μm) of the MS-30 stem were implanted in 255 patients (127 matte, 128 polished). The 5-year results showed — to our surprise — no statistical difference in the clinical outcome (5). These findings contrast with observations reported by the Exeter group (12) and Howie/Australia (20) with polished and matte versions of the tapered collarless Exeter stem. The reasons for these different results are not readily evident. However, there is not only a difference in the design — though both stems are straight and tapered — but also in the distal centralizers which were designed with different philosophies in mind. While the hollow centralizer of the Exeter

stem permits — or even enhances — subsidence of the metal stem within the cement mantle, the three-winged centraliser of the MS-30 stem becomes part of the cement mantle around the stem tip once its mission to center the stem is accomplished. One has to bear in mind, however, that increased subsidence enhances relative movement between the stem and the cement mantle.

The case for cemented titanium stems

The Müller Straight Stem, introduced in clinical practice in 1977, was originally made of Protasul 10 (CoCr alloy) and stainless steel (AISI 316-L). From 1985 until 1994, it was also manufactured of a titanium alloy, first in Ti6Al4V, later on in Ti6Al7Nb. In the early nineties, several Swiss orthopedic institutions reported an increasing rate of early development of osteolysis with the Müller Straight Stem manufactured from titanium alloy and a matte surface, which led to early revisions (29). The early development of osteolysis was unexpected, since several cemented titanium femoral stems were — and still are — on the market and provide excellent mid-term results: Céraver (Le Mouel *et al.* 26), Perfecta (Van der Straeten *et al.* 51), Bicontact (Eingartner *et al.* 11) etc. The poor results of the cemented Müller Titanium Straight Stem, however, could not be confirmed at our institution (1). There are currently contrasting clinical results with the same type of cemented stem. While there is a high rate of aseptic loosening with revision rates of 12% and 8% in two clinics, A and B, the clinics C (our own institution) and D had revision rates of only 1.6% and 1.5%, respectively. These different results were achieved with exactly the same endoprosthesis and about the same time interval of 6-8 years! In the light of these results, it is obvious that, when a significantly different number of osteolyses and revisions is observed in different institutions using the same endoprosthesis — identical in design, identical in surface and in material, — some other variables must be considered as possible causes for these differences. These variables, i.e., the reason for the above-mentioned, different results, may stem from a difference in bone cement and/or cementing technique and/or

operative technique and/or surgeon. It is to be noted that all four clinics used modern cementing techniques, but clinics A and B, the ones with the poor results, used a different cement than clinics C and D. The logical conclusion, therefore, is :

Not all bone cements are equal !

This statement was also convincingly made by the Swedish and the Norwegian Implant Registers (16, 17). From the Norwegian Implant Register of the years 1987-1998, it became obvious that the bone cements Palacos and Simplex are superior to Sulfix 6 or Boneloc ; the latter two have been withdrawn from the market in the meantime. The risk ratio with 95% confidence limits are shown in the Swedish National Hip Register of the years 1979-1998 (28) for all revisions, in all diagnoses, and aseptic loosening in osteoarthritis. The risk ratio, Sulfix 6 being the nominator (equals one) is 0.49 for Palacos-Gentamycine, 0.51 for Palacos, 0.60 for Simplex and 0.73 for CMW. An equally good outcome for the Palacos cement is given by the Norwegian Implant Register (16, 17). This register also indicated that bone cement has a greater influence on the outcome of a THR than the prosthesis itself !

Breusch's investigation in Germany (6) shows that Palacos cement is the most frequently used bone cement in Germany. On the other hand, Boneloc (in the meantime withdrawn from the market) revealed no difference in results compared to other cements when used in combination with the Exeter stem (49). This supports our conviction that a verdict on a total hip implant component should never be made in a uni-dimensional way, in other words, not without assessment of the whole system. In any case, the design, the surface, the material — including the quality of the bone cement, the operative, i.e. the cementing technique, must be considered and, last but not least, how quality control has been performed.

The significant difference in clinical outcomes of THRs with different bone cements was unexpected, since the results of the preclinical test methods of bone cements did not reveal such great differences (24). The question, therefore, arises :

Are current testing methods adequate to assess bone cements ?

Mechanical testing of different bone cement brands in compression, tension or bending alone did not show any significant differences. There is, therefore, no proof that bone cement with higher compressive and tensile strengths improves the longevity of the cement mantle. However, in contrast to static test methods, dynamic fatigue testing has proven to be a more relevant test method.

The results of the impact strength tests do not seem to be reliable either, since they do not show significant differences. There is no correlation between impact strength and clinical performance of the bone cements tested (24).

Significant differences with regard to the quality of bone cements in terms of survivorship, in accordance with the results of the Swedish and the Norwegian Implant Register, were found by Harper and Bonfield (14) with the dynamic fatigue testing method of Weibull. On the other hand, Hopf and Fritsch/Germany (18, 19) demonstrated convincingly that the application of the Wöhler method (18) to test the fatigue strength of PMMA is inadequate and misleading. Polymers — such as PMMA — behave differently from metals. With the Wöhler method to measure fatigue strength of metals, a sample has to undergo a certain number of cycles at a defined bending force level without breaking. For a number of metals, it could be shown that 10 million cycles are enough to evaluate their fatigue strength. According to Wöhler, 3-5 million cycles are appropriate for the testing of metals. Hopf & Fritsch performed their fatigue tests up to a minimum of 20 million loading cycles if a breakage of the test specimens did not occur before (18). They found that the number of loading cycles had a significant effect on the results of PMMA. In contrast to metal, PMMA has no well defined fatigue limit and can still break after a much higher number of cycles, i.e. even after 20 million cycles (18).

Low viscosity bone cements, which were introduced to achieve deeper penetration of the cement into the cancellous bone (39) and, thus, to create a stronger fixation in the bone/cement interface, have been under discussion ever since several papers

showed inferior clinical results compared to high viscosity bone cements (16, 17). No difference with regard to prosthetic fixation, however, was found between cement of low and high viscosity in a Swedish randomized multi-center study by Carlsson *et al.* in 1993 (8). Furthermore, the degree of cement viscosity cannot be the only quality criterion of bone cements. There are differences amongst high viscosity cements as well ! Due to the poor results both of Boneloc and other low viscosity cements, these have been abandoned altogether in Norway (16).

It is well known that the adhesive strength of the stem/cement interface depends on the roughness of the metal surface. The rougher the surface, the stronger the bonding. Tests at the Laboratory of Orthopedic Biomechanics in Basel (LOB) showed that the bonding of Palacos and Sulfix to a polished steel surface is quite strong, but there is no statistical difference between the measured debonding forces. Thus, we conclude that it is unlikely that different adhesive strengths of different bone cements alone would provide an explanation for the different clinical behavior.

Wear particles are the main cause of osteolysis and subsequent aseptic loosening of implants (54). However, very little is known about the interaction of different bone cements against different prosthetic surface finishes under micromotion, simulating a debonded stem/cement interface, and nothing is known about possible differences of bone cements under fretting. Different combinations of bone cement types and surfaces might hypothetically lead to different quantities of wear particles (bone cement and metal), thus explaining the different clinical outcome with one type of prosthesis (see cemented titanium stems).

In order to test our hypothesis, it was decided to perform wear studies in collaboration with the Research Department of Sulzer Orthopedics Ltd.

In vitro studies on the wear mechanism at the stem/cement interface

These wear studies were focused first of all on the basic mechanism of the development of wear

particles at the metal/cement interface. Secondly, they attempted to examine why different cements behave differently under wear conditions. Thirdly, the role of the radio-opaque additives was studied and finally, (4th goal), it was aimed at getting more insight into the importance of the surface finish of the implants. The hypothesis was that the more wear debris is generated, i.e. abraded – both from the metallic and from the cement surface - the more particles are produced, thus rendering the respective bone cement less resistant against fretting and reducing its performance in clinical practice.

In order to experimentally elucidate the wear mechanism at the metal/cement interface, the laboratory set-up has to be able to replicate *in vivo* mechanisms of aseptic loosening. The respective surfaces and the generated particles must then be studied and compared to the findings as they are known from retrieved loosened stems and bone cements.

For this purpose, a special wear machine had to be designed and constructed. Simulating the natural fretting mechanisms at the stem/cement interface must take into account the materials fretting against each other, the conditions of the fretting surfaces, the pressure between the two surfaces facing each other, the amplitude of the two surfaces' movement and, last but not least, the direction of the respective movements. Movement can only occur when the two surfaces are physically separated from each other, i.e. when they are debonded. Once debonded, the direction of the wear motion depends on the direction of the forces acting on the endoprosthesis system. Then, they are transmitted from the stem to the cement mantle and vice versa. These forces (which are eventually also responsible for the loosening of the endoprosthesis stem) become effective in three planes during gait : in the horizontal plane as rotational forces, "moving" the stem into retroversion (1) and in the axial direction, as demonstrated by subsidence of the femoral stem (2). On the other hand, axial loading increases stability of tapered stems in the cement mantle. Finally, in the frontal plane, the forces are transmitted to the calcaneus and the stem is "moved" into varus (3). The stress distribution in a total hip replacement, therefore, is a complex combination of forces acting in

all three dimensions. From the burnishing pattern on retrieved hip stems it is known that the interface micromotion is not uni-dimensional, but rather consists of translational and rotational components. A potential migration and movement of the metal/cement surfaces against each other occurs in two dimensions, the rotation of the stem within the cement mantle being the most important one (2, 4). Simulating the "natural" loosening process *in vitro*, movements of the two surfaces fretting against each other must be multi-dimensional, respecting the alternating direction of forces between the prosthesis stem and the cement/bone complex.

The fretting machine, therefore, had to fulfill the following requirements : 1. two-dimensional movements, 2. simulation of subsidence by the superpositioning of a slow linear component to the cyclic loading, 3. variable amplitudes between 20 and 200 μm , 4. normal pressures up to 4 MPa, 5. fretting frequencies of up to 1 Hz (the cyclical frequency is comparable to the average walking frequency of the human body), 6. a physiological environment using lubrication with calf serum, 7. body temperature of 37°C.

Preliminary results

The SEM pictures of *in vivo* retrieved stems with a matte surface revealed no distinct direction of scratches, indicating that the polishing of a matte metal surface is caused rather by multi- than uni-directional movements (fig. 2).

At the end of the fretting tests, very small particles, most of them smaller than 0.2 μm , were detected within the sludge of the fretted cement surface and could be identified as Zr-oxide (fig. 3). Apparently, the larger Zr-oxide conglomerates were pulverized into very small particles. In the pre-polymerized stage, however, clusters of 5 to 30 μm have been found. since the amount, i.e. the concentration of particles within the critical size range of 0.2 - 0.8 μm responsible for macrophage activation⁽²²⁾ is too small, enzymatic bone resorption by those particles is unlikely.

Laser profilometry showed no significant difference in the polishing effect of bone cement with or without the X-ray additive ZrO₂ if fretted against a

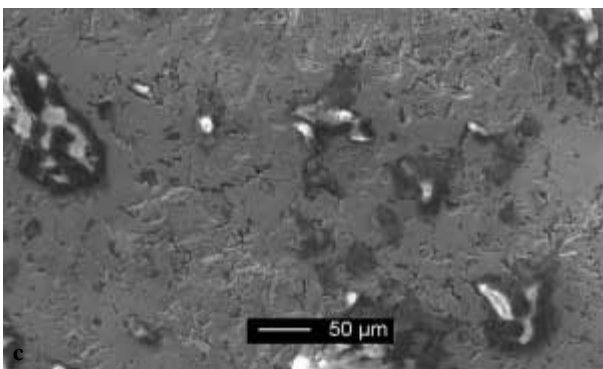
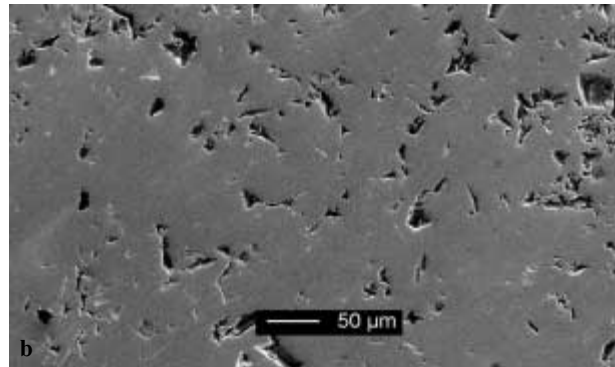
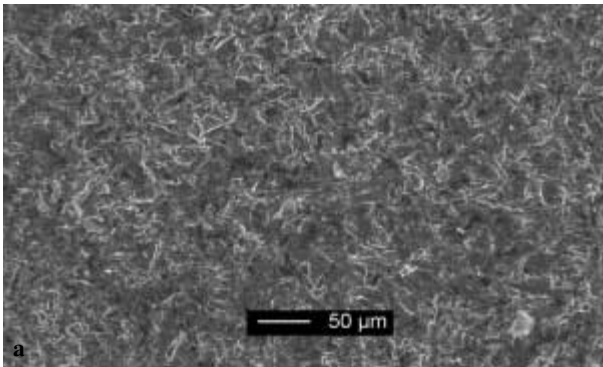


Fig. 2a. — Scanning electron micrographs of S-30 surfaces. The original S-30 matte surface ; roughness (Ra) of this surface is 1.2 μm .

Fig. 2b. — Retrieval (for aseptic loosening) of an MS-30 stem 50 months postoperatively. During wear against bone cement, the S-30 surface lost its roughness resulting in a surface with polished areas and isolated 'valleys'.

Fig. 2c. — S-30 surface after 5 million wear cycles in laboratory simulation. The surface is polished. Artifacts are caused through electrostatic effects because the sample is not coated.

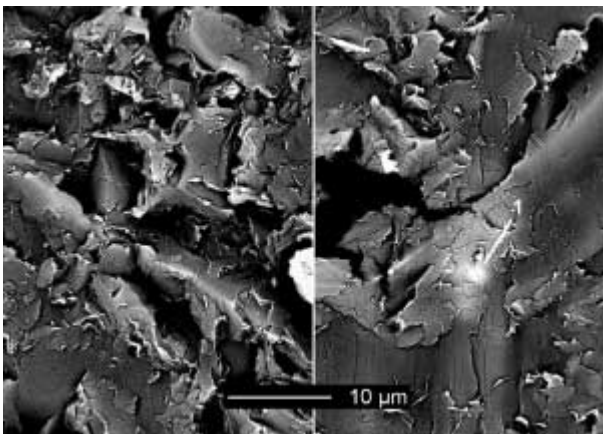


Fig. 3a. — Surface of a PMMA-bone cement sample before fretting. 1 : ZrO_2 particle totally embedded in PMMA, in Back Scattering Electron technique (BSE) shining through.

matte stainless steel (Protasul S30) surface. Surprisingly — and in contrast to our hypothesis that a “good cement” reveals less wear — Palacos R (clinically proven as the “best bone cement”) produced even more reflection and, therefore, revealed a higher polishing effect on the matte stem

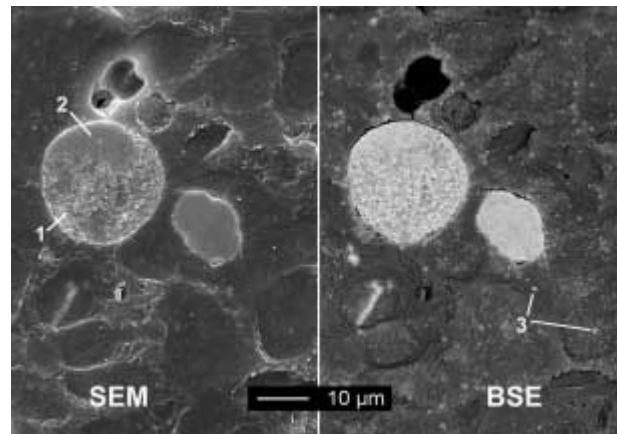


Fig. 3b. — Surface of PMMA bone cement sample after fretting of 1 million cycles against sand blasted surface of S-30 steel. Left : SEM technique. Right : BSE. 1 : Cluster of ZrO_2 particles ; in Fig 3a wholly embedded in PMMA ; in Fig. 4b, after fretting, visible and partially abraded. 2 : Sludge (polishing paste) consists of a mixture of PMMA debris, ZrO_2 particles and bovine serum. 3 : Metal particles (identification not possible).

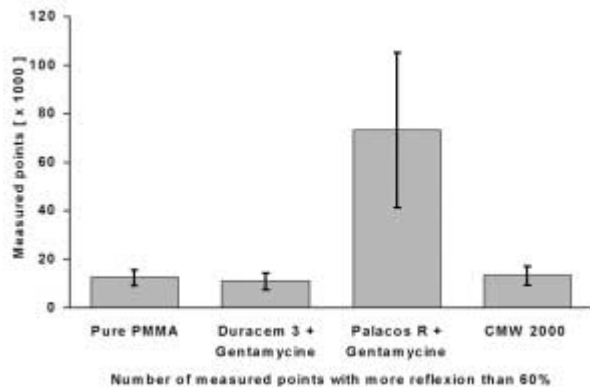


Fig. 4. — Reflection of the matte S-30 steel samples after fretting against four different bone cements (1 million cycles, 4 MPa pressure, two-dimensional fretting 100 μ m). No significant difference can be found for PMMA with or without ZrO₂ additive. ZrO₂ has no special polishing effect on an S-30 steel surface. Note the significantly higher polishing of S-30 steel after fretting against Palacos R !

surface than other bone cements as determined by laser profilometry. This finding is significant (fig. 4).

Ra measurements revealed the highest roughness reduction by Palacos.

The loss of weight in metal is very small. In experiments of Tritschler *et al.*, fretting tests of stainless steel (316L SS) versus PMMA with unidirectional movements showed that the volume of PMMA worn away was about five times greater than that of the metal (50). In our experiments, the loss of weight of the metal was about 1% of the loss of the CMW specimen and about 10% of the loss of pure PMMA, Sulfix, Duracem 3-Gentamycine and Palacos-Gentamycine. Palacos apparently removed less material from the matte S-30 surface than pure PMMA or Duracem 3, Sulfix, and the same amount as CMW 2000. The difference, however, is not significant.

The studies of the mechanisms of wear at the stem/cement interface and of the role that different bone cements play in this process, will continue.

Preliminary conclusions

Fretting movements at the stem/cement interface are two-dimensional.

The xray additive ZrO₂ does not play a significant role in the process of wear generation.

Palacos — as a clinically proven, good bone cement — has a significantly higher polishing effect. A higher polished surface is supposed to generate less wear debris by abrasion. On the other hand, Palacos produced the smallest loss of metal weight through fretting. This, however, was not significant.

Since a soft surface of PMMA cannot polish the much harder S-30 metal surface mechanically, it must be assumed that the abrasion mechanism is completed by a fretting corrosion process.

Fretting corrosion causes the formation of debris in the form of a mixture of particles of metallic oxides (but not metallic particles !), polymer and serum. Serum is rich in chlorides (NaCl, KCl, CaCl₂ with low pH), promoting the process of corrosion (50). Fretting corrosion does not produce debris particles from the metallic surface. Therefore, we were not able to find metal particles within the sludge. The metal dissolves or forms insoluble salt deposits as is the case on titanium surfaces (53).

According to the observations made up to now, we conclude that the differences in the quality of bone cements consist first of all of their capability to induce a process of fretting corrosion which - on the other hand - very much depends on the surface characteristics of the metal (roughness, nature of the oxide surface, material etc) (27). Thus, there is a potential for further improvement of results of cemented THR by improving implant surfaces as well.

Clinical experience has shown that cementing technique and quality of bone cement are more important than the implant design (16). The design of an endoprosthesis on the other hand, determines the choice of material and the specification of the metallic surface.

The future of cemented fixation

In view of the development of THR over the last two decades, there is no doubt that the question “to cement or not to cement” ? was the wrong question. The proper question today is “which technology for which implant (cup or stem), for which patient,

for which situation (primary THR or revision) and at what cost" ? The trend back to cemented fixation of femoral stems is strongly influenced by increasing cost consciousness in medical care throughout the world. Progress in THR will continue, though we find ourselves already in the upper area of the asymptotic curve of the "margin revenue".

Despite that, we can get even better results of THRs with better implant designs, better surfaces, better materials, including better bone cements and better operative technique, i.e. cementing. However, we must not forget that the surgeon is still the greatest variable.

Industry should keep in mind that better clinical results at lower costs are not achieved with ever new implant designs, but with continuous improvements in existing systems and, even more importantly, with measures to improve the operating surgeon's knowledge and skills.

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SAMENVATTING

E. W. MORSCHER, D. WIRZ. Huidige status van cementfixatie bij totale heupprothese.

De auteur overloopt de mijlpalen in de ontwikkeling van cementfixatie bij totale heupprothese. Hij legt uit waarom hij sinds lang voorstander is van hybride fixatie (gecementeerde schaft en niet-gecementeerde cup), voor patiënten ouder dan 60 jaar. Sinds jaren zijn er zeer goede cementloze cups beschikbaar; de ontwikkeling van cementloze schaft fixatie was veel moeilijker, maar nu zijn er verschillende schaftmodellen ter beschikking, die tevens goede lange termijn resultaten geven. Deze ontwikkelingsmoeilijkheden verklaren de grote verscheidenheid in het routine stemgebruik tussen de landen van Europa. Cementfixatie heeft recent weer aan populariteit gewonnen, om verschillende, waaronder economische, redenen. De auteur overloopt de voorwaarden voor een goede cementfixatie (vorm van de schaft, oppervlakte-afwerking en mogelijk gebruik van een centreermiddel), en berouwt het feit dat vele orthopeden nog rudimentaire technieken gebruiken. Hij vindt dat in de literatuur, ten onrechte, de titaniumlegeringen gediscrediteerd werden. Bovendien onderstreept hij dat de keuze van cement niemand onverschillig kan laten, omdat er inderdaad betere en slechtere zijn. Wil men niet tot foutieve besluiten komen dan moeten bij een evaluatie alle elementen in overweging worden genomen, waaronder de chirurgische techniek. Vooruitgang in de ontwikkeling van totale heup vervanging is er zeker nog te verwachten, maar de mogelijkheden worden beperkt. Verbetering van de huidige systemen, en van de huidige implantingstechniek, zullen meer bereiken dan het ontwerp van nieuwe implantaten.

RÉSUMÉ

E. W. MORSCHER, D. WIRZ. État actuel de la fixation au ciment dans l'arthroplastie par prothèse totale de hanche.

L'auteur rappelle quelques étapes marquantes du développement de l'arthroplastie par prothèse totale de la hanche, en insistant sur l'évolution des idées concernant la fixation des implants au ciment acrylique. Il rappelle les éléments qui l'ont fait opter personnellement, depuis longtemps, pour la prothèse «hybride» associant une tige cimentée à une cupule non cimentée, pour les patients de plus de 60 ans. D'excellentes cupules sans ciment sont disponibles depuis longtemps, mais du côté fémoral, les débuts ont été plus difficiles, même s'il existe actuellement plusieurs tiges fémorales dont les résultats à long terme sont excellents. Cet historique mouvementé explique que, d'un pays à l'autre en Europe, existent des différences considérables dans l'utilisation relative des prothèses cimentées ou non cimentées. Depuis quelques années, on note un regain d'intérêt pour les prothèses cimentées. Cela résulte de plusieurs facteurs, parmi lesquels il faut compter les facteurs économiques. L'auteur rappelle les conditions d'une bonne fixation d'une tige fémorale par du ciment, en regrettant qu'une proportion élevée de chirurgiens utilise encore une technique de cimentage rudimentaire. Il rappelle l'importance de la géométrie de la tige fémorale, de son état de surface; il précise l'influence possible d'un centralisateur. Il explique, sur base des résultats publiés, que l'on a jeté abusivement le discrédit sur les tiges cimentées en alliage de titane. Il rappelle un élément souvent sous-estimé: certains ciments sont nettement inférieurs à d'autres et le choix du ciment n'est en aucune façon indifférent. Il insiste sur le fait que l'évaluation d'une prothèse déterminée doit absolument prendre en considération tous les éléments sous peine d'aboutir à des conclusions erronées. Il rappelle enfin qu'il reste toujours dans l'arthroplastie prothétique de la hanche une variable importante: la qualité de la technique chirurgicale. L'arthroplastie prothétique de la hanche progressera certainement encore, même si nous sommes actuellement dans la partie supérieure d'une courbe de progression asymptotique. L'amélioration des résultats cliniques suppose, plutôt que la mise au point continuelle de nouveaux implants, le perfectionnement des systèmes qui existent et l'optimisation de la technique chirurgicale.