and there is nothing to stop the police keeping all the information obtained for as long as they like or for using it for other purposes.

This pernicious provision first appeared in an attenuated form as a recommendation of the Royal Commission on Criminal Procedure,² later to appear in a more objectionable form in the Government's discussion paper (which provoked the BMA to send a deputation to the Home Office). Now it has appeared in still more blatant and intolerable form as a clause in the new Bill.

The other cause for concern is the Data Protection Bill,³ published on 22 December, which (the Government claims) will enable the United Kingdom to ratify the European Convention for the Protection of Individuals with regard to Automatic Processing of Personal Data.⁴ There is a long history behind this Bill, beginning with the Younger Committee on Privacy⁵ and continuing with the Lindop Committee,⁶ and with the present Government's White Paper. We have referred in the past to the BMA's active participation in this important issue, and the results of the BMA's representations have been rather more effective than in the events leading up to the Police and Criminal Evidence Bill. The Data Protection Bill, however, is a grave disappointment to anyone concerned with the principles of privacy and their common sense application in medical practice. The Bill applies only to computerised records, and more than 95% of medical records are still held in manual systems. The most important amendment to be obtained in this Bill is the extension of its provisions to manual

records. There are many other omissions or unsatisfactory provisions in the Bill relating to codes of practice, the duties and powers of the registrar, the advisory committee, and the sanctions for breach of confidentiality. Regulations relating to health matters will be made by the Home Secretary, who is required only to consult with the registrar. Why is the Department of Health and Social Security not to be concerned?

The almost simultaneous appearance of these two Bills, mutually inconsistent as they are, constitutes a formidable threat to the future confidentiality of medical records. We hope that the public reaction, communicated through members of Parliament, will succeed where the representations of the medical profession, on behalf of the patient, have failed so far.

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¹ House of Commons. *Police and Criminal Evidence Bill*. London: HMSO, 1982.

² Royal Commission on Criminal Procedure. *Report*. London: HMSO, 1981 (Cmd 8092. Phillips report.)

³ House of Lords. *Data Protection Bill*. London: HMSO, 1982.

⁴ Council of Europe. *Convention for the protection of individuals with regard to automatic processing of personal data*. Strasbourg: Council of Europe, Jan 1981.

⁵ Committee on Privacy. *Report*. London: HMSO, 1972. (Cmd 5012. Younger report.)

⁶ Home Office. *Report of the Committee on Data Protection*. London: HMSO, 1978. (Cmd 7341. Lindop report.)

Regular Review

Failure patterns after total hip replacement

JOHN E NIXON

In May 1961 John Charnley described the initial favourable results of 97 total hip replacements using a new low-friction arthroplasty which he had developed with the encouragement of Sir Harry Platt and the advice of engineers at Manchester University.¹ Charnley had been stimulated by a chance encounter with a patient who had had a Judet femoral head replacement for osteoarthritis which emitted an audible squeak in certain positions. His development of a low-friction arthroplasty and its early success followed the application of basic engineering principles to prosthetic joint design; this convergence of disciplines, on the one hand the engineer and on the other the orthopaedic surgeon, was then—and remains—one of the most important associations affecting the outcome of joint-replacement surgery.

Research may some day make replacement in rheumatoid arthritis unnecessary, but in degenerative osteoarthritis of the hip nothing seems likely ever to compete with total joint replacement for the speed of recovery and quality of the early result. This comparatively new surgical procedure is therefore

here to stay, so we must look carefully at ways in which patients fail to benefit from what is a major operation. The aim of total hip replacement surgery is to relieve pain arising from the joint as a bonus to relief of pain the range of motion of the joint increases and walking improves. Failure to achieve this primary aim of a pain-free joint is classed as a failure for that patient. Müller (who after Charnley has the longest experience of total hip replacement surgery) reported in 1970 a failure rate of 1% a year and expected a failure of 10% after 10 years.² At that time he advised total hip replacement only as a last resort for patients under the age of 60—when intertrochanteric osteotomy was not possible. Now, however, with improved prosthetic design, and as surgeons become more familiar with technique of total hip replacement, low-friction arthroplasty is being offered throughout the developed world as the primary surgical treatment for painful disabling hip arthropathy with less regard for the patient's age.

I shall now try to identify certain patterns of failure that occur after total hip replacement.

Complications during operation

Complications of total hip replacement may be divided into (a) those which are specific for this operation and (b) those general complications inherent in major surgery in the elderly. Intraoperative complications of total hip replacement consist of fracturing the femur, the acetabulum, or the pubic ramus, injury to the nerves, vascular injuries, bladder injuries, and haemorrhage.

Intraoperative fractures of the femoral shaft may occur at dislocation, particularly in patients with rheumatoid arthritis and osteoporosis. Adequate release of soft tissue is advised; only one surgeon at a time should manipulate the leg since it is impossible for the combined force of two surgeons who are manipulating the limb to be judged by either surgeon; osteophytes at the margin of the acetabulum preventing dislocation should be removed, and if all else fails the neck should be divided before dislocation.

The femoral shaft may be fractured or perforated during reaming. In 1979 Talab³ *et al* reported 14 patients with perforation of the femoral shaft; eight of these had had previous hip surgery. This complication occurs more frequently when a surgeon is gaining his early experience with total hip replacement. Often the defect is not discovered until the postoperative radiograph is taken. Of the 14 patients described by Talab *et al*, four went on to develop a complete fracture of the femoral shaft postoperatively, five required revision for severe pain, and the remaining five all had pain, either constantly or intermittently; three used crutches or a walking stick.

Even after the surgeon has successfully reamed and cemented the femoral component the femoral shaft may still fracture at the time of reduction. This is more likely if a trial reduction has been omitted before cementing. The femoral shaft may fracture months or years after an otherwise successful total hip replacement; this usually occurs at the level of the tip of the stem and presents a difficult problem of management.

Fractures of the acetabulum are most commonly central, and occur most often in patients with osteoporosis or rheumatoid arthritis. The operative techniques for dealing with a fracture are similar to those used for protrusion of the acetabulum, but require a period of delayed weight bearing varying from eight to 12 weeks postoperatively.

The pubic ramus may fracture during reaming or the insertion of key holes; no specific treatment is required other than delayed weight bearing.

The overall incidence of injury to the sciatic or femoral nerve during total hip replacement is reportedly between 0.7% and 3.5%. The nerves may be damaged by direct surgical trauma, by traction with instruments, by the extreme positioning of the limb during surgery, or by heat or pressure from methylmethacrylate cement. The sciatic nerve may be damaged by overlengthening of the limb or a postoperative dislocation of the hip or by intraneural haemorrhage caused by overenthusiastic anticoagulation. The sciatic nerve is particularly at risk when the anatomy is distorted in a revision arthroplasty and in conversion of a congenital dislocation of the hip. Usually function returns within one year. If there is no sign of recovery at six weeks the nerve should be explored to remove a possible plug of cement pressing on it. Recent clinical and electrophysiological studies by Weber, Daube, and Coventry⁴ suggest that subclinical nerve injury is the rule rather than the exception after total hip replacement.

Severe arterial injury during hip surgery poses an immediate and sudden threat to life and limb. Hip surgery is performed in the vicinity of major vessels and the rarity (0.25%) of damage to these vessels is a credit to those engaged in this kind of

surgery. Nachbur and colleagues have reviewed the mechanisms.⁵ Firstly, a major artery may be perforated with the tip of a spike retractor. Secondly, injury may occur without a bleeding episode; the mechanism is intimal fracture with subsequent thrombotic occlusion of the common femoral and external iliac arteries. This occurs through overextension of atherosclerotic arteries during the manoeuvres necessary to dislocate the femoral head—in particular, extreme adduction and external rotation of the hip. The result may be an entirely satisfactory total hip replacement but persistent severe limb pain because of ischaemia. Thirdly, a major artery may be lacerated during revision of total hip replacement; scar tissue distorts the normal anatomy and causes loss of normal tissue planes, and hence the femoral, obturator, and circumflex vessels are more prone to damage. Finally, the intense heat of polymerisation of methylmethacrylate cement may coagulate a major artery. Severe ischaemic pain in the leg may be caused by a large amount of cement entering the pelvis through a hole in the acetabular floor and damaging the external iliac artery causing partial or complete occlusion.

Damage to a major artery during total hip replacement may, then, cause an occlusion of the artery by thrombosis or life-threatening haemorrhage during surgery. Patients who develop ischaemic limb pain postoperatively require prompt angiography to determine the extent of the intimal dissection and thrombosis.

Injuries to the bladder and urinary tract are fortunately rare. Lowell and colleagues reported a patient in whom cement escaped from the acetabulum into the pelvis damaging the bladder.⁶ This caused a urinary fistula, which was repaired, but infection finally spread to the hip arthroplasty, which had to be removed.

Bacterial cystitis and urinary tract infections have been reported in as high as 7-14% of patients coming to hospital for total hip replacement. Surgery should be postponed until the infection has been eradicated.

Postoperative complications

Haematoma formation is caused by poor surgical haemostasis or haemostasis which appears adequate at the time of surgery but becomes inadequate when the patient returns to normotensive conditions. Patients with blood dyscrasias or those taking prophylactic anticoagulants have a greater likelihood of developing a haematoma, as do those who are agitated and restless in the postoperative period. Haematoma formation can be reduced by the use of suction drains and retention sutures as described by Charnley.

Patients at increased risk of developing infection are the elderly and obese and those with rheumatoid arthritis and coexisting conditions such as diabetes, alcoholism, urinary tract infection,⁷ or an area of skin necrosis. Patients receiving immunosuppressive treatment or steroids or anticoagulants run an increased risk, as do those who have had previous hip surgery or a previous postoperative hip infection. Patients whose operation takes over two hours run a further increased risk of infection, as do those patients with postoperative haematomas.

Preventive measures used to reduce the chance of hip infection consist in eradicating septic foci reducing preoperative stay in hospital to less than four or five days; the avoidance of skin abrasions when shaving the skin; minimising the movement of personnel in the theatre; and the use of laminar air flow in the theatre and body-exhaust systems. Wound irriga-

tion with antibiotics and atraumatic tissue handling and double-glove technique also play their part, as do prophylactic antibiotics in cement and adequate haemostasis.

An occasional postoperative dislocation in the week or two after leaving hospital is no disgrace to the surgeon. Patients may sometimes be quite irresponsible and unreasonable during this period. With recurrent subluxation or dislocation, however, the surgeon might have to hold himself responsible for technical error of orientation or lack of tissue tension. The average incidence of dislocation and subluxation in the immediate postoperative period is 3%; they occur more commonly after a revision.

Charnley stated that increasing the length of the leg by up to 1 cm at operation might permit the patient to be mobilised earlier.⁸ Shortening of the leg, provided the soft-tissue tension is correct, presents a minor problem which is easily corrected by raising the shoe. Leg length is notoriously difficult to judge during the operation.

Specific problems

The advantages of performing a trochanteric osteotomy must be weighed up by the surgeon against the disadvantages for each individual patient. The advantages consist of improved exposure and improved positioning of the components as a direct consequence of the osteotomy, especially if the anatomy is distorted or a revision is being performed. The tension in the abductor musculature can be adjusted, and when fixing the trochanter lateral displacement can lengthen the abductor lever arm, giving it a greater mechanical advantage. Against these advantages must be weighed the increased blood loss and haematoma formation, prolonged operating time, delayed rehabilitation, and the appreciable incidence of fibrous union or non-union, which may or may not be accompanied by proximal migration of the trochanter. If the trochanter migrates proximally a lurching Trendelenburg gait may develop, which predisposes to loosening of the stem or to dislocation of the hip. Finally, the wire may break, and fragments of wire may migrate and finish up in the hip joint itself. Non-union without migration generally causes little pain or disability unless a painful pseudarthrosis develops.

The overall incidence of all the complications of trochanteric osteotomy, including trochanteric bursitis and reoperation because of painful broken wires, has been reported as high as 9.9% by Johnston⁹ in 1973 and 17.5% by Thompson and Culver¹⁰ in 1975. Review of published work, however, shows that delayed union and migration of the wire occur relatively infrequently but that pain from fractured wires is the most common cause of an unsatisfactory result after trochanteric osteotomy.

Wire breakage within the first six weeks of surgery is ominous; over half of such patients suffer trochanteric migration as time goes by and should be protected by a walking stick in the opposite hand until trochanteric union has occurred.

When low-friction arthroplasty was first used wear in the polyethylene cup was thought likely to be a major long-term problem. In fact, it has proved a minor problem compared with loosening of the components—the main cause of failure of the operation. Nevertheless, as further experience is gained of cementing techniques and with a greater understanding of the biomechanics of total hip replacement, the rate of loosening is declining in established centres such as Wrightington. Before 1965 some 1.5% of low-friction arthroplasties required revision for loosening compared with 0.21% of low-friction arthroplasties during the 10 years up to 1976. In the early days

of total hip replacement the average time elapsed before revision was seven years, but since 1971 revision has been carried out earlier (after 2.5 years), probably owing to earlier exploration rather than earlier loosening.

McBeath and Foltz¹¹ of Wisconsin defined non-infective loosening of a component as a discernible change in the position of the component or a component surrounded by gross scalloping as reported by Harris *et al*¹² but with negative bacteriological culture results either from needle aspiration or a biopsy specimen taken at revision. Harris and co-workers stated that it was generally detected radiographically before clinical symptoms or signs appeared, the delays being 2.5 and 3.2 years after surgery, respectively. Loosening of the femoral component may occur at the stem-cement interface or at the cement-bone interface, whereas loosening of the acetabulum occurs only at the cement-bone interface and not at the cup-cement interface. Charnley's experience based only on clinical evidence in patients operated on between 1966 and 1976 indicated that the femoral component loosened one and a half times more commonly than the acetabulum. Other studies based on radiographic and clinical changes, however, indicated that loosening of the femoral component is considerably more common than loosening of the acetabulum, and this is also the experience of the Nuffield Orthopaedic Centre.

Detailed studies of stem loosening have been possible only in those centres in which barium is routinely mixed with acrylic cement. A 1 mm radiolucent zone between the cement and bone in the immediate postoperative film represents an endosteal layer of cancellous bone (provided a good cementing technique was used). When this line is present at the calcar, this should confirm that the soft cancellous bone of the calcar may not have been completely removed, so that the hard cement column will not be rigidly supported here, or that cement packing here was inadequate. A 1 mm lucent zone around all or part of the cement mass occurs less commonly in the femur than in the acetabulum, where it usually indicates incomplete removal of articular cartilage and subchondral bone from the acetabulum. If the width of this zone around all or part of the cement mass increases to more than 2 mm, and especially if this increase occurs later than six months after surgery, this is evidence of loosening. Progressive linear resorption of bone, particularly near the tip of the stem, occurs when small fragments of bone and cement initiate a tissue reaction with granulomatous formation and further attrition of bone. These changes are frequently most noticeable medially. An irregular scalloping of the endosteal surface of the cortex, however, is highly suggestive of infection.

Gruen *et al* of Los Angeles have identified four different patterns of failure due to loosening of the femoral component.¹³ The first mode of failure is "pistoning" either of the stem within the cement or of the stem and cement within the bone. The second type is the medial midstem pivot, which causes a medial migration of the proximal stem and a lateral migration of the stem tip; it is caused by weak support at the level of the calcar and lack of acrylic cement distally, owing either to poor cementing technique or to a punch-out cement fracture at the tip of the stem.

The third type is calcar pivot, in which there is lack of cement distally despite perfectly adequate proximal support; and the final type is the bending cantilever type, the one most frequently accompanied by stem fracture. This is caused by cyclical bending stresses leading ultimately to fatigue fracture of the stem.

Despite the high frequency—around 20%—of loosening when judged on these radiographic criteria, only 2% of

operations require revision for loosening. Some stabilise in the new position and remain asymptomatic, and the remaining patients either have little in the way of symptoms and signs to justify a revision procedure or are considered medically unfit to undergo further surgery.

The causes of loosening of the femoral stem which are correctable are those attributable to technical error at the time of surgery. Failure to curette the soft cancellous bone from the calcar means that the cement is then not supported by dense cortical bone in its proximal third and tends to fracture. Failure to roughen the medullary canal results in poor cement-bone interdigitation: this applies especially to hip revisions. Failure to remove sufficient cancellous bone to provide a thick layer of cement around the stem gives a thin cement layer, which will crack. Any area of bony contact with the stem will tend to be resorbed. Lamination of the cement through admixture with blood during introduction increases the likelihood of fracture. Inserting cement which is already hardening and movement between the stem and the femur during hardening will predispose to loosening. Varus positioning of the femoral component and incomplete seating of the component leaving it unsupported proximally increases the likelihood of loosening later on.

McBeath and Foltz identified several further factors.¹¹ Patients who were more active postoperatively ran a greater risk of femoral stem loosening, but they did not correlate the level of activity with the age of the patient. The greater the patient's body weight, whether from obesity or his body build, the greater the likelihood of loosening.

If bone resorption occurs giving a radiolucent zone without fragmentation of the cement and pain, then clearly revision surgery is not indicated. Revision surgery is indicated only if there is both clinically and radiographically unequivocal evidence of loosening together with symptoms severe enough to justify major surgery. If the hip is painful but radiographs fail to show any loosening then arthrography and screening of the hip while applying traction and compression forces may be useful.

Loosening of the cup requires separate consideration. A radiolucent zone superlaterally at the cement-bone interface in the immediate postoperative radiographic film indicates usually that articular cartilage and subchondral bone have not been removed and does not imply loosening. Later a lucent zone measuring up to 2 mm across may appear owing to a dense fibrous membrane. This membrane probably develops in response to cyclical loading of the cup and the introduction of cement by finger pressure—much less than the pressure at which the femoral cement is introduced. If this zone increases to more than 2 mm and particularly if this occurs more than six months after surgery loosening should be suspected. The loosening is more common in patients with rheumatoid arthritis and those who are overweight.

Loosening of the cup is preventable when it is due to technical error. The technical errors consist of inadequate cement support of the cup, especially superiorly and posteriorly, or pressing the cup too firmly and extruding cement, causing contact between the cup and high spots of bone, which results in poor pressurisation of the cement. Failure to remove cartilage and subchondral bone or to remove loose bony fragments or using cement that is already hardening and will not enter the interstices of the bone may give rise to loosening later on. The use of too small a cup which will not pressurise the cement within a large acetabulum or moving the cup while the cement is hardening can cause failure later. Finally, mal-positioning of the cup so that the femoral neck impinges on the

side of the cup causes undue localised pressure on the cup.

The absolute indications for revision of the cup are fracture of the medial wall of the acetabulum with displacement of the cup into the pelvis. A relative indication for revision would be the gradual erosion of the cup into the pelvis, when delay would make surgery more difficult. Symptomatic loosening of the cup and migration is a relative indication for cup revision.

Fracture of the femoral component occurred in 0.23% of the first 6500 patients given total hip replacements. So far there have been no reports of fractures in the stems made from the newer higher-strength metallic alloys of reinforced stems.

The tensile strength of the metals used for the femoral component is so great that direct trauma, such as a fall, will not cause fracturing. Fracturing is usually the result of several years of cyclical loading causing molecular slip and metal fatigue. Some stems will bend before breaking, but those made of cobalt chrome and some stainless-steel stems may fracture without deformation. Bending of the stem and incomplete fracture are usually painless unless the stem is loose. Even a complete fracture may be painless if the proximal third is adequately supported by cement and bone. The usual occurrence, however, is of a complete fracture of the stem with a sudden onset of severe pain increased by attempts at weight bearing. Metallurgical studies have shown that hairline cracks appear anterolaterally, which is the area of maximum tensile loading.

The early metallurgical problems (such as microporosity of the metals and large grain size), which had a detrimental effect on the strength of the metal, have largely been resolved, and most failures are now more attributable to technical errors at surgery. Cementing the femoral component into varus position and use of a prosthesis with a long neck or narrow stem, increase the likelihood of fatigue fracture, as do non-union of the greater trochanter and inadequate proximal support of the prosthesis by cement and bone. These latter problems may not necessarily be due to technical error but arise from resorption of the calcar over the years. Resorption of the calcar may be due to disuse atrophy, ischaemia, failure to remove soft cancellous bone of the calcar at surgery, and placing the hip into a varus position.

Other factors associated with a higher incidence of stem failure are increased physical activity and obesity.

Finally, heterotopic ossification is seldom a cause of failure of total hip replacement. DeLee and co-workers¹⁴ studied 2173 hips over an average of 1.8 years after operation and found ectopic bone formation in almost 15%. In almost 5% of patients the ectopic bone occupied less than half of the distance between the femur and the pelvis, while in 10% it occupied more than half of this distance. Ectopic bone developed initially as a faint indistinct density on the hip radiographs affecting the abductors and the psoas. This may first become apparent two to three weeks postoperatively and may develop into an extensive bone mass within three months. It matures into a plaque or number of plaques at nine to 12 months and usually does not progress further. Complete bony ankylosis is rare, and only 2-7% of patients with heterotopic ossification have any appreciable loss of function. It remains, therefore, a radiological curiosity rather than a serious clinical problem in most patients.

General complications of total hip replacement

When discussing failure patterns after total hip replacement we must bear in mind that the patients are elderly: over 60%

are over 60. These patients have to survive the general medical complications associated with any form of major surgery in the elderly. Inevitably, some of those requiring surgery will be suffering from hypertension, obesity, diabetes, varicose veins, and possibly poor renal function and it may be in their best interest not to subject them to major surgery.

At the time of prosthetic implantation patients may suffer from a transient cardiovascular collapse or irreversible cardiac arrest. This reaction has been thought to be due to methyl-methacrylate or fat and bone marrow entering the blood stream.

The most common serious medical complication after hip surgery is thromboembolism. Prophylactic anticoagulation presents a dilemma to the surgeon, who must weigh the advantages and effectiveness of prophylaxis against the disadvantages of a potential increase in wound complications and bleeding from other sites. Charnley asserted that patients under 40 rarely developed thromboembolism and that the risk was greater in patients with degenerative arthritis than in those with rheumatoid arthritis.

Discussion of the prevention of thromboembolism is made more difficult by the different criteria used in different studies to make the diagnosis and the wide variety of differing regimens used for prophylaxis. As many as 90% of patients who develop a pulmonary embolus may show no clinical evidence whatsoever of deep venous thrombosis except possibly unilateral oedema of the leg and a low-grade fever. Fatal pulmonary emboli develop in between 1.8% and 3.4% of patients without prophylaxis.¹⁵ Two-thirds of patients who die from pulmonary embolism will do so within the first 30 minutes, and patients who survive long enough for the diagnosis to be established usually survive if appropriate treatment is started, provided that there is no severe associated disease. Fatal pulmonary emboli are rare in patients who have clinical thrombophlebitis and are effectively anticoagulated, because the clot is usually firmly adherent to the lumen of the vein. A few phlebograms performed at the Nuffield Orthopaedic Centre during total hip replacement have shown that the femoral vein is occluded at the time of adduction and external rotation of the lower limb. These procedures may damage the intima and predispose to the formation of thrombus at this site.

The basic principles of prophylaxis for thromboembolism consist in raising the leg in the early postoperative period, using antiembolic stockings, and hourly active leg exercises from the first day postoperatively (especially of the calf),

together with early mobilisation though there are no definite data to suggest that the last reduces the incidence of deep venous thrombosis. Drugs which are used for prophylaxis include warfarin, low molecular weight dextran, low-dose heparin, and aspirin, or a combination of these. Most investigators believe that the reduction in the incidence of pulmonary embolism justifies the increased risk of bleeding complications. Lester Lowe¹⁶ suggested the use of 5000 international units of heparin subcutaneously every eight hours, which gives measurable prophylaxis in 97% of patients. He believed that warfarin when used preoperatively gives a similar protective effect to low-dose subcutaneous heparin. Harris showed, however, that a fifth of patients taking preoperative warfarin had excessive operative bleeding and postoperative haematoma formation, which increases the likelihood of developing a wound infection. Goss *et al* have reported a reduction of the incidence of deep venous thrombosis and pulmonary embolus with a combination of low-dose heparin and warfarin,¹⁷ but they again point to a 13% incidence of wound haematomas. Only 2% of this 13% occurred in the first three days after operation; the remaining 11% occurred after three days and hence were probably due to the anticoagulation.

Myocardial infarction and congestive cardiac failure are the second and third most common life-threatening complications. Predisposing factors such as intraoperative hypoxaemia and hypovolaemia must be avoided. The average overall mortality for total hip replacement is 1.2%.

Conclusions

The operation of total hip replacement may fail for various reasons. Some of the figures quoted in this paper on the incidence of failure were based on early series of patients. Prosthetic design has improved considerably, and as surgeons have become familiar with the risks and reasons for failure of total hip replacement their efforts have reduced the total failure rate considerably. What is still uncertain, however—and likely to remain so for the next 10 or 15 years—is the long term failure rate. This is a fundamental consideration because it concerns the acceptance of acrylic cement by living tissue.

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