Veterans Administration

Key references in biomaterials: Bone/biomaterial interface in orthopedic joint implants†

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I. CEMENT-BONE INTERFACE HISTOLOGY

1. Albrektsson T, Linder L: A method for short- and long-term *in vivo* study of the bone-implant interface. *Clin Orthop* 159: 269–273, 1981.
2. Charnley J, Crawford WJ: Histology of bone in contact with self-curing acrylic cement. *Proc Brit Orthop Assn J Bone Joint Surg* 50B: 228, 1968.
3. Charnley J, Follacci FM, Hammond BT: The long-term reaction of bone to self-curing acrylic cement. A long-term histological study in man. *J Bone Joint Surg* 50B: 822–829, 1968.
4. Charnley J: The reaction of bone to self-curing acrylic cement. *J Bone Joint Surg* 52B: 340–353, 1970.
5. Charnley J: *Acrylic Cement in Orthopaedic Surgery.* Baltimore, MD: Williams & Wilkins, 1970.
6. Charnley J: Cement-bone interface. In: *Low Friction Arthroplasty of the Hip. Theory and Practice.* New York: Springer, 1979, ch. 4, pp 25–40.
7. Danckwardt-Lilliestrom G: Reaming of the medullary cavity and its effect on diaphyseal bone. A fluorochromic, microangiographic and histologic study on the rabbit tibia and dog femur. *Acta Orthop Scand*, supp 128, 1969.
8. Draenert K: Histomorphology of the bone-to-cement interface: remodeling of the cortex and revascularization of the medullary canal in animal experiments. In: *The Hip*. St. Louis, MO: CV Mosby, 1981, ch. 7, pp 71–110. (Proc. Hip Society.)
9. Draenert K, Rudigier J: Histomorphologie des Knochen-Zement-Kontaktes. Eine tierexperimentelle Phaenomenologie der knochernen Umbauvorgange. *Chirurg* 49: 276–285, 1978.
10. Draenert K: Histomorphology of the boundary surfaces of bone and acrylic cement. In: *Scanning Electron Microscopy* (Vol. II). Chicago, IL: IIT Research Institute, 1977, pp 229–238. (Proc. Workshop on Biomedical Applications–SEM in Medical Prosthesis.)
11. Eitenmueller J, Wolbert R, Eisen E: Die Auswirkungen der Blutzirkulation auf die Polymerisations-Temperatur von Palacos. Eine vergleichende tierexperimentelle Untersuchung (The effect of circulation on the polymerizing temperature of Palacos. An experimental study). *Arch Orthop Traumat Surg* 98: 61–67, 1981.
12. Feith R: Side-effects of acrylic cement implanted in bone. A histological, (micro)angiographic, fluorescence-microscopic and autoradiographic study in the rabbit femur. *Acta Orthop Scand* supp No. 161, 1975.
13. Freeman MAR, Bradley GW, Revell PA: Observation upon the interface between bone and polymethylmethacrylate cement. *J Bone Joint Surg* 64B: 489–493, 1982.
14. Gitelis S, Chen RW, Anderson GB, Galante JO, Rostoker W, Andriacchi TP: The influence of early weight-bearing on experimental total hip arthroplasties in dogs. *Clin Orthop* 169: 291–302, 1982.
15. Gitelis S, Andersson GB, Galante JO, Rostoker W, Andriacchi TP: The effects of weight bearing on the bone-cement interface total hip arthroplasty: An experimental study in dogs. In: *The Hip*. St. Louis, MO: CV Mosby, 1979, ch. 8, pp. 188–197. (Proc. Hip Society.)
16. Harris WH, Schiller AL, Scholler JM, Freiburg RA, Scott R: Extensive localized bone resorption in the femur following total hip replacement. *J Bone Joint Surg* 58A: 612–618, 1976.
17. Hedley AK, Clarke IC, Bloebaum RD, Moreland J, Gruen TA, Coster I, Amstutz HC: Viability and cement fixation of the femoral head in canine hip surface replacement. In: *The Hip*. St. Louis, MO: CV Mosby, 1979, ch. 7, pp 160–187. (Proc. Hip Society.)
18. Homsy C, Tullos HS, Anderson MS, Differante NM, King JW: Some physiological aspects of prosthesis stabilization with acrylic polymer. *Clin Orthop* 83: 317–328, 1972.
19. Hulbert SF, Richbourg HL, Klawitter JJ, Sauer BW: Evaluation of a metal-ceramic composite hip prosthesis. *J Biomed Mater Res Symp* 6: 189–198, 1975.
20. Jefferiss CD, Lee AC, Ling RSM: Thermal aspects of self-curing polymethylmethacrylate. *J Bone Joint Surg* 57B: 511–518, 1975.
21. Linder L: The tissue response to bone cement. In: *Biocompatibility of Orthopaedic Implants* (vol. 2). Williams DF, (ed.) (vol. II). Boca Raton, FL: CRC Press, 1982, pp 1–23.
22. Linder L: Die Gewebsvertraeglichkeit von bariumsulfathaltigem und bariumsulfatfreien Knochenzement. *Art Orthop Unfall-Chir* 89: 179–185, 1977.
23. Linder L: Reaction of bone to the acute chemical trauma of bone cement. *J Bone Joint Surg* 59A: 82–87, 1977.
24. Linder L: Acute local tissue effects of polymerizing acrylic bone cement. *Clin Orthop* 115: 303–312, 1976.
25. Linder L: Tissue reaction to methyl methacrylate

manomer. A comparative study in the rabbit's ear on the toxicity of methyl methacrylate monomer of varying composition. *Acta Orthop Scand* 47: 3–10, 1976.

26. Linder L, Romanus M: Acute local tissue effects of polymerizing acrylic bone cement. An intravital microscopic study in the hamster's cheek pouch on the chemically induced microvascular changes. *Clin Orthop* 115: 303–312, 1976.

27. Linder L, Lundskog J: Incorporation of steel, titanium, and vitallium in bone. *Injury* 6: 277–285, 1975.

28. Lindwer J, van den Hooff A: The influence of acrylic cement on the femur of the dog: A histological study. *Acta Orthop Scand* 46: 657–671, 1975.

29. Lundskog J: Heat and bone tissue. An experimental investigation of the thermal properties of bone and threshold levels for thermal injury. *Scand J Plast Reconst Surg* supp 9, 1972.

30. McCarthy TC, Wells MK: Mechanical properties of bone-prosthesis interface: a study of total hip joint prostheses stabilized with methyl methacrylate and porous ceramic. *Biomed Sci Inst* 13: 41–46, 1977.

31. Miller J, Burke DL, Stachiewicz JW, Ahmed AM, Kelebay LC: Pathophysiology of loosening of femoral components in total hip arthroplasty. In: *The Hip*. St. Louis, MO : CV Mosby, 1978, ch. 3, pp. 64–86. (Proc. Hip Society.)

32. Modig J, Busch C, Olerud S, Saldeen T, Waernbaum G: Arterial hypotension and hypoxemia during total hip replacement: The importance of thromboplastic products, fat embolism, and acrylic monomers. *Acta Anaesthesiol Scand* 19: 28–43, 1975.

33. Nathanson D, Gettleman L, Schnitman P, Shklar G: Histologic response to porous PMMA implant materials. *J Biomed Mater Res* 12: 13–33, 1978.

34. Park JB, Barb W, Kenner GH, von Recum AF: Intramedullary fixation of artificial hip joints with bone cement-precoated implants. II. Density and histological study. *J Biomed Mater Res* 16: 459–469, 1982.

35. Pedley RB, Meachim G, Gray T: Identification of acrylic cement particles in tissue. *Ann Biomed Eng* 7: 319–328, 1979.

36. Petty W: Methyl methacrylate concentration in tissues adjacent to bone cement. *J Biomed Mater Res* 14: 427–434, 1980.

37. Radin EL, Rubim CT, Thrasher EL, Lanyon LE, Crugnola AM, Schiller AS, Rose RM: Changes in the bone-cement interface after total hip replacement. An *in vivo* animal study. *J Bone Joint Surg* 64A: 1188–1200, 1982.

38. Rhinelander FW: Experimental reaming of the proximal femur and acrylic cement implantation. *Clin Orthop* 141: 74–89, 1979.

39. Rhinelander FW, Nelson CL, Jr, Stewart RD, Stewart CL: Experimental reaming of the proximal femur and acrylic cement implantation: Vascular and histologic effects. In: *The Hip*. St. Louis, MO: CV Mosby, 1979, ch. 6, pp. 127–159. (Proc. Hip Society.)

40. Rietz KA: Polymer osteosynthesis. III. Segmental resection of femur and fixation of endoprosthesis with methyl methacrylate in dogs. *Acta Chir Scand* supp 388, 1968.

41. Sew Hoy AL, Hedley AK, Clarke IC, Gruen TAW, Amstutz HC, Coster I, Moreland JR: The acetabular cement-bone interface in experimental arthroplasties in dogs. *Clin Orthop* 155: 231–243, 1981.

42. Slooff TJJH: The influence of acrylic cement. An experimental study. *Acta Orthop Scand* 42: 465–481, 1971.

43. Spinelli RA: A study of the interface between bone and acrylic cement by scanning-electron microscopy. *Ital J Orthop Traumat* 2: 103–115, 1976.

44. Vernon-Roberts B, Freeman MAR: The tissue response to total joint replacement prostheses. In: *The Scientific Basis of Joint Replacement*. Swanson SAV, Freeman MAR, (eds.). New York: Wiley, 1977, pp 86–129.

45. Willert HG, Buchhorn G, Zichner L, Mueller K, Semlitsch M: Oberflachenstrukturen von Knochenzement. *Z Orthop* 117: 674–683, 1979.

46. Willert HG, Ludwig J, Semlitsch M: Reaction of bone to methacrylate after hip arthroplasty. A long-term gross, light microscopic and scanning electron microscope study. *J Bone Joint Surg* 56A: 1368–1382, 1974.

47. Wiltse LL, Hall RH, Stenehjem C: Experimental studies regarding the possible use of self-curing acrylic in orthopaedic surgery. *J Bone Joint Surg* 39A: 961–972, 1957.

48. Wroblewski TJ, Park JB, Kenner GH, von Recum AF: Prosthetic coxofemoral joint replacement in the goose (anser Sp.): II. Histologic and mechanical interface evaluations. *Vet Surg* 10: 106–112, 1981.

II. ACRYLIC BONE CEMENT AND THE EXOTHERM

1. Amstutz HC, Gruen T: Clinical application of poly-

methyl methacrylate for total joint replacement. In: *Current Practice in Orthopaedics Surgery,* Ahstrom J, (ed.). St. Louis, MO: CV Mosby, 1973, pp 158–182.

2. Biehl G, Harms J, Hanser U: Experimentelle Untersuchungen über die Warmentwicklung im Knochen bei der Polymerisation von Knochenzement. *Arch Orthop Unfall-Chir* 78: 62–69, 1974.
3. Clattenburg R, Colica J, Cohen S, Cook N: Thermal properties of cancellous bone. *J Biomed Mater Res* 9: 169–182, 1975.
4. Debrunner HU: Die Erwarmung von Knochenzement bei der Polymerisation. *Arch Orthop Unfall-Chir* 78: 309–318, 1974.
5. Debrunner HU, Wettstein A, Hofer P: The polymerization of self-curing acrylic cements and problems due to the cement anchorage of joint prostheses. In: *Advances in Artificial Hip and Knee Joint Technology*, Schaldach M, Hohmann D (eds.). New York: Springer, 1976, pp 294–324.
6 DiPisa JA, Sih GS, Berman PT: The temperature problem at the bone-acrylic cement interface of the total hip replacement. *Clin Orthop* 121: 95, 1976.
7. Eitenmuller J, Wolbert R, Eisen E: Die Auswirkungen der Blutzirkulation auf die Polymerisationstemperatur von Palacos (The effect of circulation on the polymerizing temperature of Palacos). *Arch Orthop Traumat Surg* 98: 61–67, 1981.
8. Eitenmueller J, Schmidt KH, Wolbert R, Reichmann W: Vergleichende tierexperimentelle Untersuchungen der Polymerisationstemperatur von Palacos mit und ohne Blutsperre. Vortrag No. 30 bei der Vereinigung Niedernheinisch-West gaelischer Chirurgen in Muenster, Sept., 1979.
9. Eitenmueller J, Eisen E, Reichmann W: Temperaturbedingte Veraenderungen und Reaktionen des Knochens beim Anlegen von Bohrloechern zur Durchfuehrung von Osteosynthesesn. *Leitz-Mitt, Wiss U Tech* 7 (4): 104–110, Sept., 1978.
10. Homsy, CA, Tullos HS, Anderson MS, Differante NM, King JW: Some physiological aspects of prosthesis stabilization with acrylic polymer. *Clin Orthop* 83: 317–328, 1972.
11. Huiskes R, Slooff TJ: Thermal injury of cancellous bone, following pressurized penetration of acrylic bone cement. *Trans Orthop Res Soc* 6: 134, 1981.
12. Hupfauer W, Ulatowski L: Die Temperaturentwicklung verschiedener Knochenzemente waehrend des Abhartungvorganges. *Arch Orthop Unfall-Chir* 72: 174–184, 1972.
13. Hupfauer W, Ulatowski L: Thermographische Messungen Polymerisations Temperaturen Kunststoffe. *Arch Orthop Unfall-Chir* 70: 70–82, 1971.
14. Jefferiss CD, Lee AJC, Ling RSM: Thermal aspects of self-curing polymethylmethacrylate. *J Bone Joint Surg* 57B(4): 511–518, 1975.
15. Labitzke R, Paulus M: Intraoperative Temperaturmessungen in der Hueftchirurgie waehrend der Polymerisation des Knochenzements Palacos (Intraoperative temperature measurements in hip surgery during the polymerization of Palacos bone cement). *Arch Orthop Unfall-Chir* 79: 341–346, 1974.
16. Lundskog J: Heat and bone tissue. *Scand J Plast Reconst Surg*, supp. no. 9, 1972.
17. Matthews LS, Hirsch C: Temperatures measured in human cortical bone when drilling. *J Bone Joint Surg* 54A: 297–308, 1972.
18. Meyer PR, Jr, Lautenschlager EP, Moore BK: On the setting properties of acrylic bone cement. *J Bone Joint Surg* 55A: 149–156, 1973.
19. Ohnsorge J, Goelbel G: Die Verwendung unterkuhlter Metallendoprothesen in der Hueftchirurgie. *Z Orthop* 107: 683–696, 1970.
20. Ohnsorge J, Goebel G: Oberflachentemperaturen des abhartenden Knochenzementes Palacos beim Veraenkern von Metallendoprothese in Oberschenkelmarkraum. *Arch Orthop Unfall-Chir* 67: 89–100, 1969.
21. Ohnsorge J, Kroesen K: Thermoelektrische Temperaturmessungen des abhartenden Knochenzementes (Palacos). *Z Orthop* 106: 476–482, 1969.
22. Reckling FW, Dillon WL: The bone-cement interface temperature during total joint replacement. *J Bone Joint Surg* 59A: 80–82, 1977.
23. Schatzker J, Horne JG, Summer-Smith G, Sanderson R, Murnaghan JP: Methyl methacrylate cement: Its curing temperature and effect on articular cartilage. *Canad J Surg* 18: 172–175, 1975.
24. Seidel H, Eggert A, Pietsch H: Intraoperative Temperaturmessungen an der Zementknochengrenze bei TEP-Implantation. *Arch Orthop Unfall-Chir* 90: 251–257, 1977.
25. Seyfarth M, Jaster D: Temperaturmessungen waehrend der Polymerisation von Knochenzement. *Orthop Traumat* 22: 662, 1975.
26. Taoka H, Kinoshita I, Morimoto H, Sasaki T, Ogawa Y, Shimakawa T: Temperature in the interface between bone and acrylic bone cement. *Tokushima J Exp Med* 27: 89–92, 1980.

III. RADIOGRAPHIC ANALYSIS OF INTERFACES IN TOTAL HIP REPLACEMENT

1. Aglietti P, Rinonapoli E, DiFilippo P: A radiographic study of Charnley total hip prostheses. *Ital J Orthop Traumat* 7: 321–335, 1982.
2 Amstutz HC, Smith RK: Total hip replacement following failed femoral hemiarthroplasty. *J Bone Joint Surg* 61A: 1161–1166, 1979.
3. Beckenbaugh RD, Ilstrup DM: Total hip arthroplasty: A review of three hundred and thirty-three cases with long follow-up. *J Bone Joint Surg* 60A: 306–313, 1978.
4. Bergstrom B, Lidgren L, Lindberg L: Radiographic abnormalities caused by postoperative infection following total hip arthroplasty. *Clin Orthop* 99: 95–102, 1974.
5. Cameron HU, McNeice GM: A correlation of radiographic "modes of failure" with clinical failure of cemented stem-type femoral components. *Clin Orthop* 150: 154–158, 1980.
6. Carlsson AS, Gentz CF: Mechanical loosening of the femoral head prosthesis in the Charnley total hip arthroplasty. *Clin Orthop* 147: 262–270, 1980.
7. Chandler HP, Reineck FT, Wixson RL, McCarthy C: Total hip replacement in patients younger than thirty years old. A five-year follow-up study. *J Bone Joint Surg* 63A: 1426–1434, 1981.
8. Cotterill P, Hunter GA, Tile M: A radiographic analysis of 166 Charnley-Mueller total hip arthroplasties. *Clin Orthop* 163: 120–126, 1982.
9. DeLee J, Charnley J: Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop* 121: 20–32, 1976.
10. DeSmet AA, Kramer D, Martel W: The metal-cement interface in total hip prostheses. *Am J Roentgenol* 129: 279–282, 1977.
11. Fornasier VL, Cameron HU: The femoral stem/cement interface in total hip replacement. *Clin Orthop* 116: 249–252, 1976.
12. Griffith MJ, Seidenstein MK, Williams D, Charnley J: Eight-year results of Charnley arthroplasties of the hip with special references to the behavior of cement. *Clin Orthop* 137: 24–36, 1978.
13. Gruen TA, McNeice GM, Amstutz HC: "Modes of failure" of cemented stem-type femoral components. A radiographic analysis of loosening. *Clin Orthop* 141: 17–27, 1978.
14. Harris WH, McCarthy JC, O'Neill DA: Femoral component loosening using contemporary techniques of femoral cement fixation. *J Bone Joint Surg* 64A: 1063–1067, 1982.
15. Harris WH, White RE, Jr.: Socket fixation using a metal-backed acetabular component for total hip replacement. A minimum five-year follow-up. *J Bone Joint Surg* 64A: 745–748, 1982.
16. Loudon JR, Charnley J: Subsidence of the femoral prosthesis in total hip replacement in relation to the design of the stem. *J Bone Joint Surg* 62B: 450–453, 1980.
17. Miller J, Burke DL, Stachiewicz JW, Ahmed AM, Kelebay LC: Pathophysiology of loosening of femoral components in total hip arthroplasty. Clinical and experimental study of cement fracture and loosening of the cement-bone interface. In: *The Hip*. St. Louis, MO: CV Mosby, 1978, pp 64–86. (Proc. Hip Society.)
18. Moreland JR, Gruen TA, Mai L, Amstutz HC: Aseptic loosening of total hip replacement: Incidence and significance. In: *The Hip*. St. Louis, MO: CV Mosby, 1980, pp 281–291. (Proc. of The Hip Society.)
19. Reckling FW, Asher MA, Dillon WL: A longitudinal study of the radiolucent line at the bone-cement interface following total joint replacement procedure. *J Bone Joint Surg* 59A: 355–358, 1977.
20. Salvati EA, Wilson PD, Jr., Jolley MN, Vakili F, Aglietti P, Brown GC: A ten-year follow-up study of our first one hundred consecutive Charnley total hip replacement. *J Bone Joint Surg* 63A: 753–767, 1981.
21. Salvati EA, Im VC, Aglietti P, Wilson PD, Jr.: Radiology of total hip replacements. *Clin Orthop* 121: 74–82, 1976.
22. Schneider R, Freiberger RH, Ghelman B, Ranawat CS: Radiologic evaluation of painful joint prostheses. *Clin Orthop* 170: 156–168, 1982.
23. Stauffer RN: Ten-year follow-up study of total hip replacement. With particular reference to roentgenographic loosening of the components. *J Bone Joint Surg* 64A: 983–990, 1982.

IV. INTERFACE BIOMECHANICS IN TOTAL HIP REPLACEMENT

1. Andersson GBJ, Freeman MAR, Swanson SAV: Loosening of the cemented acetabular cup in

total hip replacement. *J Bone Joint Surg* 54B: 590–599, 1972.

2. Breed AL: Experimental production of vascular hypotension, and bone marrow and fat embolism with methyl methacrylate cement. *Clin Orthop* 102: 227–244, 1974.
3. Charnley J: A biomechanical analysis of the use of cement to anchor the femoral prosthesis. *J Bone Joint Surg* 47B: 354–363, 1965.
4. Charnley J: The bonding of prosthesis to bone by cement. *J Bone Joint Surg* 46B: 518–529, 1964.
5. Charnley J, Kettlewell L: The elimination of slip between prosthesis and femur. *J Bone Joint Surg* 47B: 56–60, 1965.
6. Chen SC, Lowe SA, Scales JT, Ansell RH: An *in vitro* experiment to determine the efficiency of the McKee-Farrar acetabular component in relation to torsional force. *Acta Orthop Scand* 45: 429–435, 1974.
7. Ducheyne P, Aernoudt E, DeMeester P, Martens M, Mulier JC, Van Leeuwer D: Factors governing the mechanical behavior of the implant-porous coating-trabecular bone interface. *J Biomech* 11: 297–307, 1978.
8. Halawa M, Lee AJC, Ling RSM, Vangala SS: The shear strength of trabecular bone from the femur, and some factors affecting the shear strength of the cement-bone interface. *Arch Orthop Traumat Surg* 92: 19–30, 1978.
9. Hallin G, Modig J, Nordgren L, Olerud S: The intramedullary pressure during the bone marrow trauma of total hip replacement surgery. *Upsala J Med Sci* 79: 51–54, 1974.
10. Hampton SJ, Andriacchi TP, Galante JO: Three-dimensional stress analysis of the femoral stem of a total hip prosthesis. *J Biomech* 13: 443–448, 1980.
11. Huiskes R: Stress analyses of implanted orthopaedic joint prostheses for optimal design and fixation. *Acta Orthop Belg* 46: 711–727, 1980.
12. Huiskes R: Some fundamental aspects of human joint replacement. Analyses of stresses and heat conduction in bone-prosthesis structures. *Acta Orthop Scand* supp 185, 1980.
13. Itami Y, Akamatsu N, Tomita Y, Nagai M: The direct fixation system of total hip prosthesis. Research of the possibilities of fixing total hip prosthesis directly to bone. *Arch Orthop Traumat Surg* 100: 11–17, 1982.
14. Itami Y, Akamatsu N, Tomita Y, Nagai M: A cementless system of total hip prosthesis. Experimental studies on total hip prosthesis in dogs. *Arch Orthop Traumat Surg* 100: 183–189, 1982.
15. Jaeger M, Kuesswetter W, Ruett J, Ungethuem M, Burkhardt R: Loosening of the cemented prosthetic cup in total hip replacement by torsional loading. In: *Biopolymers and Biomechanics of Connective Tissue*, Hartman F (ed.). New York: Springer, 1974, pp 421–426.
16. Kenesi C, Lortat-Jacob A: Le scellement aux silicones des prostheses de Moore. *Rev Chir Orthop* 59: 469–475, 1973.
17. Koelbel R: Problems of mechanical strength of the interface PMMA-Cancellous bone in implant fixation. In: *Biopolymers and Biomechanics of Connective Tissue*. Hartmann F (ed.). New York: Springer, 1974, pp 409–415.
18. McCarthy TC, Wells MK: Mechanical properties of the bone-prosthesis interface: A study of total hip joint prostheses stabilized with methyl methacrylate and porous ceramic. *Biomed Sci Instrum* 13: 41–46, 1977.
19. McCarthy TC, Wells MK, Gorman HA: Bone-methyl methacrylate interfacial shear strength: An experimental study in dogs. *Am J Vet Res* 38: 75–79, 1979.
20. Markolf KL, Amstutz HC: *In vitro* measurement of bone-acrylic interface pressure during femoral component insertion. *Clin Orthop* 121: 60–66, 1976.
21. Markolf KL, Amstutz HC, Hirschowitz DL: The effect of calcar contact on femoral component micromovement. A mechanical study. *J Bone Joint Surg* 62A: 1315–1323, 1980.
22. Niederer PG, Chiquet C, Eulenberger J: Hueftendoprothesen mit oberflaechen strukturierten Verankerungsschaften. Resultate von statischen Belastungsversuchen (Endoprostheses of the hip with surface structural anchorage shafts. Results of static loading experiments). *Unfallheilkunde* 81: 205–210, 1978.
23. Oh I, Carlsson CE, Tomford WW, Harris WH: Improved fixation of the femoral component after total hip replacement using a methacrylate intramedullary plug. *J Bone Joint Surg* 60A: 608–613, 1978.
24. Petty W, Miller GJ, Piotrowski G: *In vitro* evaluation of the effect of acetabular prosthesis implantation on human cadaver pelves. *Bull Prosthet Res* 17: 80–89, 1980.
25. Pilliar RM, Bratina WJ: Micromechanical bonding at a porous surface–structured implant interface. The effect of implant stressing. *J Biomed Eng* 2: 49–53, 1980.
26. Savino AW, Andersson GBJ, Andriacchi TP, Hampton S, Galante JO: The influence of femoral stem thickness and implantation technique on the strength

of the bone cement bond. *Acta Orthop Scand* 53: 23–27, 1982.

27. Slooff TJJH: De invloed van hat acrylcement bij de fixatie van de heupendoprothese (The influence of the acrylic cement on the fixation of the hip endoprosthesis. A clinical, theoretical, histological and mechanical study. Nijmegen, The Netherlands: Katholieke Universiteit, 1970. Ph. D. thesis.
28. Volz RG, Wilson RJ: Factors affecting the mechanical stability of the cemented acetabular component in total hip replacement. *J Bone Joint Surg* 59A: 501–504, 1977.
29. Witt AN, Hackenbroch, MH, Jr.: Probleme der Pfannenverankerung im Rahmen der Totalen Ersatzarthroplastik des Hueftgelenks. *Z Orthop* 110: 292–304, 1972.
30. Yettram AL, Wright KWJ: Biomechanics of the femoral component of total hip prostheses with particular references to the stress in the bone cement. *J Biomed Eng* 1: 281–285, 1979.

V. RADIOGRAPHIC ANALYSIS OF INTERFACES IN TOTAL KNEE REPLACEMENT

1. Ahlberg A, Linden B: The radiolucent zone in arthroplasty of the knee. *Acta Orthop Scand* 48: 687–690, 1977.
2. Blaha JD, Insler HP, Freeman MAR, Revell PA, Todd RC: The fixation of a proximal tibial polyethylene prosthesis without cement. *J Bone Joint Surg* 64B: 326–335, 1982.
3. Cameron HU, McNeice GM: Mechanical failure modes in total knee replacement. *Arch Orthop Traumat Surg* 98: 135–138, 1982.
4. Ducheyne P, Kagan A, Lacey JA: Failure of total knee arthroplasty due to loosening and deformation of the tibial component. *J Bone Joint Surg* 60A: 384–392, 1978.
5. Insall JN, Lachiewicz PF, Burstein AH: The posterior stabilized condylar prosthesis: a modification of the condylar design. Two- to four-year clinical experience. *J Bone Joint Surg* 64A: 1317–1323, 1982.
6. Insall J, Ranawat CS, Scott WN, Walker PS: Total condylar knee replacement: preliminary report. *Clin Orthop* 120: 149–154, 1976.
7. Reckling FW, Asher MA, Dillon WL: A longitudinal study of the radiolucent line at the bone-cement interface following total joint-replacement procedures. *J Bone Joint Surg* 59A: 355–358, 1977.
8. Ritter MA, Gioe TJ, Stringer EA: Radiolucency surrounding the posterior cruciate condylar total knee prosthetic components. *Clin Orthop* 160: 149–152, 1981.

VI. INTERFACE BIOMECHANICS IN TOTAL KNEE REPLACEMENT

1. Askew MJ, Lewis JL: Analysis of model variables and fixation post length effects on stresses around a prostheses in the proximal tibia. *J Biomech Eng* 103: 239–245, 1981.
2. Bargren JH, Day WH, Freeman MAR, Swanson SAV: Mechanical tests in the tibial component of non-hinged knee prosthesis. *J Bone Joint Surg* 60B: 256–261, 1978.
3. Cameron HU, McNeice GM: Mechanical failure modes in total knee replacement. *Arch Orthop Trauma Surg* 98: 135–138, 1981.
4. Chao EY, Mullen JO: Theoretical and experimental analyses of the interface strength in geometric total knee replacement. *Closed Loop* 6: 3–16, 1976.
5. Ducheyne P, Kagan A, Lacey JA: Failure of total knee arthroplasty due to loosening and deformation of the tibial component. *J Bone Joint Surg* 60A: 384–391, 1975.
6. Kagan A: Mechanical causes of loosening in knee joint replacement of the knee. *J Biomech* 10: 387–139, 1977.
7. Lewis JL, Askew MJ, Jaycox DP: A comparative evaluation of tibial component designs of total knee prostheses. *J Bone Joint Surg* 64A: 129–135, 1981.
8. Reilly D, Walker PS, Ben-Dov M, Ewald FC: Effects of tibial components on load transfer in the upper tibia. *Clin Orthop* 165: 273–282, 1982.
9. Volz RG, Fulcher WH: Mechanical stability of cemented tibial components with and without intramedullary stem design. *Cont Orthop* 2: 340–344, 1980.
10. Walker PS, Ranawat C, Insall J: Fixation of the tibial components of condylar replacement knee prostheses. *J Biomech* 9: 269–275, 1976.
11. Walker PS, Greene D, Reilly D, Thatcher J, Ben-Dov M, Ewald FC: Fixation of tibial components of knee prostheses. *J Bone Joint Surg* 63A: 258–267, 1981.
12. Walker PS, Thatcher J, Ewald FC, Milden J: Variables affecting the fixation of tibial components. *Eng Med* 11: 83–87, 1982.
13. Werner F, Foster D, Murray DG: The influence of

design on the transmission of torque across knee prostheses. *J Bone Joint Surg* 60A: 342–348, 1978.

VII. BIOMATERIALS INTERFACE BIOMECHANICS

1. Anand SC, St. John KR, Moyle DD, Williams DF: Stress distribution in porous-surfaced medullary implants. *Ann Biomed Eng* 5: 410–420, 1977.
2. Barb W, Park JB, Kenner GH, von Recum AF: Intramedullary fixation of artificial hip joints with bone cement-precoated implants. I. Interfacial strengths. *J Biomed Mater Res* 16: 447–458, 1982.
3. Beaumont PWR, Young RJ: Strength and fracture of acrylic bone cement and acrylic cement-metal interfaces. In: *Plastics in Medicine and Surgery*. Conf. Proc. of the Plastics and Rubber Institute, London, 1975.
4. Beaumont PWR, Plumpton B: The strength of acrylic bone cements and acrylic cement-stainless steel interfaces. Part 2. The shear strength of an acrylic cement-stainless steel interface. *J Mat Sci* 12: 1853–1856, 1977.
5. Bergmann G, Kolbel R, Rohlmann A: Mechanische Eigenschaften einer Verbindung von spongiosem Knochen und Polymethylmethacrylat. IV. Zug-Dauerfestigkeit (Mechanical properties of bonding between cancellous bone and polymethylmetacrylate. IV. Tensile fatigue strength). *Arch Orthop Unfall-Chir* 87: 223–233, 1977.
6. Bobyn JD, Wilson GJ, MacGregor DC, Pilliar RM, Weatherly GC: Effect of pore size on the peel strength of attachment of fibrous tissue to porous-surfaced implants. *J Biomed Mater Res* 16: 571–584, 1982.
7. Bobyn JD, Cameron HU, Abdulla D, Pilliar RM, Weatherly GC: Biologic fixation and bone modeling with an unconstrained canine total knee prosthesis. *Clin Orthop* 166: 301–312, 1982.
8. Fornasier VL, Cameron HU: The femoral stem/cement interface in total hip replacement. *Clin Orthop* 116: 249–252, 1976.
9. Greenwald AS, Narten NC, Wilde AH: Points in the technique of recementing in the revision of an implant arthroplasty. *J Bone Joint Surg* 60B: 107–110, 1978.
10. Gruen TA, Markolf KL, Amstutz HC: Effects of laminations and blood entrapment of the strength of acrylic bone cement. *Clin Orthop* 119: 250–255, 1976.
11. Halawa M, Lee AJC, Ling RSM, Vangala SS: The shear strength of trabecular bone from the femur and some factors affecting the shear strength of the cement-bone interface. *Arch Orthop Traumat Surg* 92: 19–30, 1978.
12. Jobbins B, Flowers M, Reeves BG: Fixation of orthopaedic implants under tensile loading. *Biomed Eng* 8: 380–383, 1973.
13. Keller JC, Lautenschlager EP, Marshall GW, Jr., Meyer PR, Jr.: Factors affecting surgical alloy/bone cement interface adhesion. *J Biomed Mater Res* 14: 639–651, 1980.
14. Kolbel R: Mechanische Eigenschaften einer Verbindung von spongiosem Knochen und Polymethylmetacrylat bei periodischer Belastung. *Arch Orthop Unfall-Chir* 80: 31–43, 1974.
15. Kolbel R, Boenick U, Krieger W, Wilk R: Mechanische Eigenschaften den Verbindung von spongiosem Knochen mit Polymethylmetacrylat bei statischer Belastung. II. Scherfestigkeit. *Arch Orthop Unfall-Chir* 77: 339–347, 1973.
16. Kolbel R, Boenick U: Mechanische Eigenschaften der Verbindung zwischen spongiosem Knochen mit Polymethylmetacrylat bei statischer Belastung. I. Zugfestigkeit. *Arch Orthop Unfall-Chir* 73: 89–97, 1972.
17. Krause WR, Krug W, Miller J: Strength of the cement-bone interface. *Clin Orthop* 163: 290–299, 1982.
18. Kwak BM, Lim OK, Kim YY, Rim K: An investigation of the effect of cement thickness on an implant by finite element stress analysis. *Intern Orthop* 2: 315–319, 1979.
19. Lange DR: The mechanical bonding of methacrylate to cancellous bone. *J Bone Joint Surg* 61A: 254–256, 1979.
20. Park JB, von Recum AF, Gratzick GE: Pre-coated orthopaedic implants with bone cement. *Biomat Med Dev Artif Organs* 7: 41–53, 1979.
21. Raab S, Ahmed AM, Provan JW: Thin film PMMA precoating for improved implant bone-cement fixation. *J Biomed Mater Res* 16: 679–704, 1982.
22. Raab S, Ahmed AM, Provan JW: The quasistatic and fatigue performance of the implant/bone-cement interface. *J Biomed Mater Res* 15: 159–182, 1981.
23. Svensson NL, Valliappan S, Wood RD: Stress analysis of human femur with implanted Charnley prosthesis. *J Biomech* 10: 581–588, 1977.
24. Weigand AJ, Meyer ML, Ling JS: Scanning-electron-microscopy observations and mechanical characteristics of ion-beam-sputtered surgical implant

alloys. *NASA Techn Memo* (TM-X-3533), Washington, DC, 1977.

25. Welsh RP, Pillar RM, Macnab I: Surgical implants. The role of surface porosity in fixation to bone and acrylic. *J Bone Joint Surg* 53A: 963–977, 1971.

VIII. CERAMIC/BONE INTERFACE

1. Beckham CA, Greenlee TK, Jr., Crebo AR: Bone formation at a ceramic implant interface. *Calc Tiss Res* 8: 165–171, 1971.
2. Benum P, Lyng S, Alm T, Johannessen N: Porous ceramic as a bone substitute in the medial condyle of the tibia. An experimental study in sheep. Long-term observations. *Acta Orthop Scand* 48: 150–157, 1977.
3. Benum P, Lyng S, Bo O, Rafn I, Haffner JFW: Porous ceramics as a bone substitute in the medial condyle of the tibia. *Acta Orthop Scand* 47: 158–166, 1976.
4. Clarke IC, Phillips W, McKellop H, Coster IR, Hedley AK, Amstutz HC: Development of a ceramic surface replacement for the hip. An experimental Sialon model. *Biomat Med Dev Artif Organs* 7: 111–126, 1979.
5. Dorre E, Geduldig D, Happel M, Lade R, Prussner P, Willert HG, Zichner L: Animal studies on bone ingrowth kinetics of ceramic material under dynamic stress. *J Biomed Mater Res Symp* 7: 493–502, 1976.
6. Esslinger JO, Rutkowski EJ: Studies on the skeletal attachment of experimental hip prostheses in the pygmy goat and the dog. *J Biomed Mater Res Symp* 4: 187–193, 1973.
7. Graves GA, Noyes FR, Villanueva AR: The influence of compositional variations on bone ingrowth of implanted porous calcium aluminate ceramics. *J Biomed Mater Res Symp* 6: 17–22, 1975.
8. Graves GA, Hentrich RL, Stein HG, Bajpai PK: Resorbable ceramic implants. *J Biomed Mater Res Symp* 2: pt. I, 91–115, 1971.
9. Griss P, Silber R, Merkle B, Haehner K, Heimke G, Krempien B: Biomechanically induced tissue reactions after Al_2O_3 ceramic hip joint replacement. Experimental and early clinical results. *J Biomed Mater Res Symp* 10: 519–528, 1976.
10. Griss P, von Andrian-Werburg HF, Heimke G, Krempien B, Reipa S, Hartung HJ, Lauterbach HJ: Ergebnisse der experimentellen Prüfung und klinische Anwendungsmöglichkeiten der Aluminiumoxydkeramik in der Alloarthroplastik. *Orthop Z* 113: 756–759, 1975.
11. Griss P, Heimke G, von Andrian-Werburg H, Krempien B, Reipa S, Lauterbach HJ, Hartung HJ: Morphological and biomechanical aspects of Al_2O_3 ceramic joint replacement. Experimental results and design considerations for human endoprostheses. *J Biomed Mater Res Symp* 6: 177–188, 1975.
12. Griss P, Krempien B, von Andrian-Werburg J, Heimke G, Fleiner R, Diehm T: Experimental analysis of ceramic-tissue interactions. A morphologic, fluorescenceoptic, and radiographic study on dense aluminum oxide ceramic in various animals. *J Biomed Mater Res Symp* 5: 39–58, 1974.
13. Harms J, Mausle E: Tissue reaction to ceramic implant material. *J Biomed Mater Res* 13: 67–87, 1979.
14. Heimke G, Griss P, Jentschura G, Werner E: Die Aussagefähigkeit histologischer Befunde zur Beurteilung von Knochenersatzwerkstoffen. *Arch Orthop Traumat Surg* 91: 267–176, 1978.
15. Heimke G, Beisler W, von Andrian-Werburg H, Griss P, Krempien B: Untersuchungen an Implantaten aus Al_2O_3 Keramik. *Berichte Deutsche Ker Ges* 50: 4–8, 1973.
16. Hentrich RL, Graves GA, Stein HG, Bajpai PK: An evaluation of inert and resorbable ceramics for future clinical orthopaedic applications. *J Biomed Mater Res* 5: 25–51, 1971.
17. Hulbert SF, Young FA, Mathews RS, Klawitter JJ, Talbert CD, Stelling FH: Potential of ceramic materials as permanently implantable skeletal prostheses. *J Biomed Mater Res* 4: 433–455, 1970.
18. Hulbert SF, Richbourg HL, Klawitter JJ, Sauer BW: Evaluation of a metal-ceramic composite hip prosthesis. *J Biomed Mater Res Symp* 6: 189–198, 1975.
19. Hulbert SF, Matthews JR, Klawitter JJ, Sauer BW, Leonard RB: Effect of stress on tissue ingrowth into porous aluminum oxide. *J Biomed Mater Res Symp* 5: 85–97, 1974.
20. Hulbert SF, Cooke FW, Klawitter JJ, Leonard RB, Sauer BW, Moyle DD, Skinner HB: Attachment of prostheses to the musculoskeletal system by tissue ingrowth and mechanical interlocking. *J Biomed Mater Res Symp* 4: 1–23, 1973.
21. Hulbert SF, Morrison SJ, Klawitter JJ: Tissue reaction to three ceramics of porous and non-porous structure. *J Biomed Mater Res* 6: 347–374, 1972.
22. Klawitter JJ, Hulbert SF: Application of porous ceramics for the attachment of load bearing internal

orthopaedic applications. *J Biomed Mater Res Symp* 2: pt. I, 161–229, 1971.

23. Klawitter JJ, Weinstein AM: The status of porous materials to obtain direct skeletal attachment by tissue ingrowth. *Acta Orthop Belg* 40: 755–765, 1974.
24. Koster K, Heide H, Konig R: Histologische Untersuchungen an der Grenzfläche zwischen Knochengewebe und Calciumphosphat-, Calciumaluminat-, und Aluminiumoxidkeramik. *Z Orthop* 115: 693–699, 1977.
25. Krempien B, Griss P, Heimke G, von Andrian-Werburg H, Hartung HJ, Reipar S, Lauterbach HJ: Remodeling dynamics of cortical bone under the influence of ceramic implants in sheep. *Acta Orthop Belg* 40: 624–638, 1974.
26. Lyng S, Sudman E, Hulbert SF, Sauer BW: Fixation of permanent orthopaedic prosthesis. Use of ceramics in the tibial-plateau. *Acta Orthop Scand* 44: 694–701, 1973.
27. Park JB, Kenner GH: Effect of electrical stimulation of the interfacial tensile strength and amount of bone formation. *Biomat Med Dev Artif Organs* 4: 225–233, 1976.
28. Park JB, Kenner GH: Effect of electrical stimulation on the tensile strength of the porous implant and bone interface. *Biomat Med Dev Artif Organs* 3: 233–243, 1975.
29. Park JB, Salmon NN, Kenner GH, von Recum AF: Preliminary studies on the effects of direct current on the bone/porous implant interfaces. *Ann Biomed Eng* 8: 93–101, 1980.
30. Predecki P, Auslaender BA, Stephan JE, Mooney VL, Stanitski C: Attachment of bone to threaded implants by ingrowth and mechanical interlocking. *J Biomed Mater Res* 6: 401–412, 1972.
31. Predecki P, Stephan JE, Auslaender BA, Mooney VL, Kirkland K: Kinetics of bone growth into cylindrical channels in aluminum oxide and titanium. *J Biomed Mater Res* 6: 375–400, 1972.
32. Rhinelander FW, Rouweyha M, Milner JC: Microvascular and histogenic responses to implantation of a porous ceramic into bone. *J Biomed Mater Res* 5: 81–112, 1971.
33. Riska EB, Holmstrom T: Replacement of the femoral head by ceramic endoprosthesis. An experimental study on rabbits. *Acta Orthop Scand* 52: 207–213, 1981.
34. Salzer M, Knahr K, Locke H, Stark N: Cement-free bioceramic double-cup endoprosthesis of the hip joint. *Clin Orthop* 134: 80–86, 1978.
35. Salzer M, Locke H, Plenke H, Jr., Punzet G, Stark N, Zweymuller K: Experience with bioceramic endoprostheses of the total hip. In: *Advances in Artificial Hip and Knee Joint Technology*, Schaldach M, Hohmann D (eds.). New York: Springer, 1976, pp 459–474.
36. Salzer M, Zweymuller L, Locke H, Zeibig A, Stark N, Plenk Jr. H, Punzet G: Further experimental and clinical experience with aluminum oxide endoprostheses. *J Biomed Mater Res* 10: 847–856, 1976.
37. Selting WJ, Bhaskar SN: Structural strength of the interface between bone and nondegradable porous ceramic implants. *J Dent Res* 52: 91–95, 1973.
38. Weinstein AM, Klawitter JJ, Cleveland TW, Amoss DC: Electrical stimulation of bone growth into porous Al_2O_3. *J Biomed Mater Res* 10: 231–247, 1976.
39. Welsh RP, Macnab I: Ceramics in surgery. *J Biomed Mater Res Symp* 2: pt. I, 231–249, 1971.

IX. BIOACTIVE-CERAMIC/BONE INTERFACE

1. Blencke BA, Bromer H, Deutscher KK: Compatibility and long-term stability of glass-ceramic implants. *J Biomed Mater Res* 12: 307–316, 1978.
2. Clark AE, Hench LL, Paschall HA: The influence of surface chemistry on implant interface histology: A theoretical basis for implant materials section. *J Biomed Mater Res* 10: 161–174, 1976.
3. Ducheyne P, Hench LL, Kagan A, Martens M, Mulier JC: Short-term bonding behavior of Bioglass coatings on metal substrate. *Arch Orthop Traumat Surg* 94: 155–160, 1979.
4. Fuchs GA, Deutscher K: Glass-ceramic coated implants. A simple model for a loaded hip prosthesis with a bioactive interface. *Arch Orthop Traumat Surg* 98: 121–126, 1981.
5. Greenlee TK, Beckham CA, Crebo AR, Malmorg JC: Glass ceramic bone implants. *J Biomed Mater Res* 6: 235–244, 1972.
6. Greenspan DC, Hench LL: Chemical and mechanical behavior of bioglass-coated alumina. *J Biomed Mater Res Symp* 10: 503–510, 1976.
7. Griss P, Greenspan DC, Heimke G, Krempien B, Buchinger R, Hench LL, Jentschura G: Evaluation of bioglass-coated Al_2O_3 total hip prosthesis in sheep. *J Biomed Mater Res Symp* 7: 511–518, 1976.
8. Griss P, Werner E, Heimke G, Buchinger R: Vergleichende experimentelle Untersuchungen an Bioglas (L.L. Hench), Al_2O_3 Keramik and mid mod. Bioglas beschichtiger Al_2O_3 Keramik. I. Ergebnisse

mit unbelasteten Implantaten. *Arch Orthop Unfall-Chir* 90: 15–27, 1977.

9. Griss P, Werner E, Heimke G, Raute-Kreinsen U: Vergleichende experimentelle Untersuchungen an Bioglas (L.L. Hench), Al_2O_3 Keramik und mit mod. Bioglas beschichtiger Al_2O_3 Keramik. II. Ergebnisse mit belasteten Implantaten. *Arch Orthop Traumat Surg* 92: 199–210, 1978.
10. Gross UM, Strunz V: The anchoring of glass ceramics of different solubility in the femur of the rat. *J Biomed Mater Res* 14: 607–618, 1980.
11. Hench LL, Pantano CG, Jr., Buscemi PJ, Greenspan DC: Analysis of Bioglass fixation of hip prostheses. *J Biomed Mater Res* 11: 267–282, 1977.
12. Hench LL, Paschall HA: Histochemical responses at a biomaterial's interface. *J Biomed Mater Res Symp* 5: 49–64, 1974.
13. Hench LL, Paschall HA: Direct chemical bond of bioactive glass-ceramic materials to bone and muscle. *J Biomed Mater Res Symp* 4: 25–42, 1973.
14. Hench LL, Splinter RJ, Allen WC, Greenlee TK: Bonding mechanisms at the interface of ceramic prosthetic materials. *J Biomed Mater Res Symp* 2: 117–141, 1971.
15. Piotrowski G, Hench LL, Allen WC, Miller GJ: Mechanical studies of the bone bioglass interfacial bond. *J Biomed Mater Res Symp* 6: 47–61, 1975.
16. Wilson J, Pigott GH, Schoen FJ, Hench LL: Toxicology and biocompatibility of bioglass. *J Biomed Mater Res* 15: 805–817, 1981.

X. POROUS COBALT-CHROMIUM-MOLBYDENUM ALLOY

1. Bobyn JD, Wilson GJ, MacGregor DC, Pilliar RM, Weatherly GC: Effect of pore size on the peel strength of attachment of fibrous tissue to porous-surfaced implants. *J Biomed Mater Res* 16: 571–584, 1982.
2. Bobyn JD, Cameron HU, Abdulla D, Pilliar RM, Weatherly GC: Biologic fixation and bone remodeling with an unconstrained canine total knee prosthesis. *Clin Orthop* 166: 301–312, 1982.
3. Bobyn JD, Pilliar RM, Cameron HU, Weatherly GC: Osteogenic phenomena across endosteal bone-implant spaces with porous surfaced intramedullary implants. *Acta Orthop Scand* 52: 145–153, 1981.
4. Bobyn JD, Pilliar RM, Cameron HU, Weatherly GC: The optimum pore size for the fixation of porous-surfaced metal implants by the ingrowth of bone. *Clin Orthop* 150: 263–270, 1980.
5. Bobyn JD, Pilliar RM, Cameron HU, Weatherly GC, Kent GM: The effect of porous surface configuration on the tensile strength of fixation of implants by bone ingrowth. *Clin Orthop* 149: 291–298, 1980.
6. Cameron HU: Essential design considerations for microporous implants: preliminary communication. *J Roy Soc Med* 74: 887–891, 1981.
7. Cameron HU, Pilliar RM, Macnab I: The rate of bone ingrowth into porous metal. *J Biomed Mater Res* 10: 295–302, 1976.
8. Cameron HU, Pilliar RM, Macnab I: Porous Vitallium in implant surgery. *J Biomed Mater Res* 8: 283–289, 1974.
9. Cameron HU, Pilliar RM, Macnab I: Fixation of loose bodies in joints. *Clin Orthop* 100: 309–314, 1974.
10. Cameron HU, Pilliar RM, Macnab I: The effect of movement on the bonding of porous metal to bone. *J Biomed Mater Res* 7: 301-311, 1973.
11. Cameron HU, Macnab I, Pilliar RM: Porous surfaced Vitallium staples. *So Afr J Surg* 10: 63–70, 1972.
12. Collier JP, Colligan GA, Brown SA: Bone ingrowth into dynamically loaded porous-coated intramedullary nails. *J Biomed Mater Res Symp* 7: 485–492, 1976.
13. Cook SD, Weinstein AM, Luedemann R, Lavernia C, Skinner HB, Klawitter JJ: The effect of intramedullary implants on bone strains and remodeling in the femur. *Biomat Med Dev Artif Organs* 10: 21–40, 1982.
14. Hedley AK, Clarke IC, Kozinn SC, Coster I, Gruen T, Amstutz HC: Porous ingrowth fixation of the femoral component in a canine surface replacement of the hip. *Clin Orthop* 163: 300–311, 1982.
15. Hirschhorn JS, Reynolds JT: Powder metallurgy fabrication of cobalt alloy surgical implant materials. In: *Research in Medical Materials*, Korostoff E (ed.). NY: Plenum, 1969, pp 137–150.
16. Pilliar RM, Cameron HU, Welsh RP, Binnington AG: Radiographic and morphologic studies of load-bearing porous-surfaced structured implants. *Clin Orthop* 156: 249–256, 1981.
17. Pilliar RM, Cameron HU, Macnab I: Porous surface layered prosthetic devices. *Biomed Eng* 10: 126–131, 1975.
18. Robertson DM, St. Pierre L, Chahal R: Preliminary observations of bone ingrowth into porous materials. *J Biomed Mater Res* 10: 335–344, 1976.

19. Welsh RP, Pilliar RM, Macnab I: Surgical implants. The role of surface porosity in fixation to bone and acrylic. *J Bone Joint Surg* 53A: 963–977, 1971.

XI. POROUS TITANIUM

1. Albrektsson T, Branemark RI, Hansson HA, Lindstrom J: Osseointegrated titanium implants. Requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. *Acta Orthop Scand* 52: 155–170, 1981.
2. Andersson GBJ, Galante JO, Rostoker W: Segmental replacement of the femur in baboons. Comparison of fixation through bone ingrowth with and without methyl methacrylate. *Arch Orthop Traumat Surg* 99: 47–51, 1981.
3. Andersson GBJ, Gaechter A, Galante JO, Rostoker W: Segmental replacement of long bones in baboons using a fiber titanium implant. *J Bone Joint Surg* 60A: 31–40, 1978.
4. Beder DE, Eade G: An investigation of tissue tolerance to titanium metal implants in dogs. *Surgery* 39: 470, 1956.
5. Clemow AJT, Weinstein AM, Klawitter JJ, Koeneman J, Anderson J: Interface mechanics of porous titanium implants. *J Biomed Mater Res* 15: 73–82, 1981.
6. Colella SM, Miller AG, Stang RF, Stoebe TG: Fixation of porous titanium implants in cortical bone enhanced by electrical stimulation. *J Biomed Mater Res* 15: 37–46, 1981.
7. Esslinger JO, Rutkowsky EJ: Studies on the skeletal attachment of experimental hip prostheses in the pygmy goat and the dog. *J Biomed Mater Res Symp* 4: 187–193, 1973.
8. Galante J, Rostoker W, Lueck R, Ray RD: Sintered fiber metal composites as a basis for attachment of implants to bone. *J Bone Joint Surg* 53A: 101–114, 1971.
9. Galante J, Rostoker W: Fiber metal composites in the fixation of skeletal prosthesis. *J Biomed Mater Res Symp* 4: 43–61, 1973.
10. Galante J, Rostoker W: Fiber metal composites in the fixation of skeletal prostheses. In: *Internal Structural Prostheses*, Washington, D.C.: Nat Acad Sci, 1973, pp 58–67.
11. Hahn H, Palich W: Preliminary evaluation of porous metal surfaced titanium for orthopaedic implants. *J Biomed Mater Res* 4: 571–577, 1970.
12. Hirschhorn JS, McBeath AA, Dustoor MR: Porous titanium surgical implant materials. *J Biomed Mater Res Symp* 2: 49–67, 1971.
13. Homsy CA, Cain TE, Kessler FB, Anderson MS, King KW: Porous implant system for prosthesis stabilization. *Clin Orthop* 89: 220–235, 1972.
14. Karagianes MT, Wheeler KR, Nilles JL: Cartilage repair over porous metal implants. *Arch Pathol* 99: 398–400, 1975.
15. Karagianes MT: Porous metals as a hard tissue substitute. *Biomat Med Dev Artif Organs* 1: 171–181, 1973.
16. Lembert E, Galante J, Rostoker W: Fixation of skeletal replacement by fiber metal composites. *Clin Orthop* 87: 303–310, 1972.
17. Linder L, Lundskog J: Incorporation of stainless steel, titanium and vitallium in bone. *Injury* 6: 277–285, 1975.
18. Linder L, Albrektsson T, Branemark PI, Hansson HA, Ivarsson B, Jonsson U, Lundstom I: Electron microscopic analysis of the bone-titanium interface. *Acta Orthop Scand* 54: 45–52, 1983.
19. Meachim G, Williams DF: Changes in nonosseous tissue adjacent to titanium implants. *J Biomed Mater Res* 7: 555–572, 1973.
20. Muster D, Jaeger JM, Bouzouita M, Burggraf C, Baltzinger C: Application of physical surface methods to the study of the stability and structure of bone-metal interfaces. *Anat Clin* 4: 183–188, 1982.
21. Murray GAW, Semple JC: Transfer of tensile loads from a prosthesis to bone using porous titanium. *J Bone Joint Surg* 63B: 138–141, 1981.
22. Nilles JL, Karagianes MT, Wheeler KR: Porous titanium alloy for fixation of knee prostheses. *J Biomed Mater Res Symp* 5: 319–328, 1974.
23. Nilles JL, Coletti M, Wilson C: Biomechanical evaluation of bone-porous material interface. *J Biomed Mater Res* 7: 231–251, 1973.
24. Nilles JL, Lapitsky M: Biomechanical investigations of bone-porous carbon and porous metal interface. *J Biomed Mater Res Symp* 4: 63–84, 1973.
25. Predecki P, Stephan JE, Auslander BA, Mooney VL, Kirkland K: Kinetics of bone growth into cylindrical channels in alumina and titanium. *J Biomed Mater Res* 6: 375–400, 1972.
26. Solar RJ, Pollack SR, Korostoff E: *In vitro* corrosion testing of titanium surgical implant alloys: An approach to understanding titanium release from implants. *J Biomed Mater Res* 12: 217–250, 1979.
27. Wheeler KR, Marshall RP, Sump KR: Porous metal as a hard tissue substitute. Part II. Porous metal

properties. *Biomat Med Dev Artif Organs* 1: 337–348, 1973.

28. Williams DF: Titanium as a metal for implantation. Part 2. Biological properties and clinical applications. *J Med Eng Technol* 1: 266–270, 1977.
29. Williams DF, Adams D: A histochemical method for the determination of titanium in tissues surrounding implants. *J Clin Pathol* 29: 657–661, 1976.
30. Williams DF, Meachim G: A combined metallurgical and histological study of tissue-prosthesis interactions in orthopaedic patients. *J Biomed Mater Res Symp* 5: pt. I, 1–9, 1974.
31. Williams DF, Adams D, Mort E: A histochemical method for the detection of metals in tissues, with reference to the use of surgical implants. *Microsc Acta* 81: 1–7, 1978.

XII. POROUS STAINLESS STEEL

1. Davis CM, Shackelford JF: Analysis of bone-composite interfacial strengths. *Biomat Med Dev Artif Organs* 9: 47–55, 1981.
2. Ducheyne P, Hench LL, Kagan A, Martens M, Bursens A, Mulier JC: Effect of hydroxyapatite impregnation on skeletal bonding of porous-coated implants. *J Biomed Mater Res* 14: 225–237, 1980.
3. Ducheyne P, DeMeester P, Aernoudt E: Isostatically compacted metal fiber porous coatings for bone ingrowth. *Powder Metall Intern* 11: 115–119, 1979.
4. Ducheyne P, Martens M, DeMeester P, Aernoudt E, Mulier JC: Influence of a functional dynamic loading on bone ingrowth into surface pores of orthopaedic implants. *J Biomed Mater Res* 11: 811–838, 1977.
5. Ducheyne P, Martens M, Aernoudt E, Mulier J, DeMeester P: Skeletal fixation by metal fiber coating of the implant. *Arch Orthop Belg* 40: 799–805, 1974.
6. Dustoor MR, Hirschhorn JS: Porous metal implants. In: *Modern Development in Powder Metallurgy*, Hausner HH, Taubemblat PW (eds.). Princeton, NJ: Metal Powder Industries Federation, 1977, vol 11, pp 247–262.
7. Dustoor MR, Hirschhorn JS: Porous surgical implants. *Powder Metall Int* 5: 183–188, 1973.
8. Martens M, Ducheyne P, DeMeester P, Mulier JC: Skeletal fixation of implants by bone ingrowth into surface pores. *Arch Orthop Traum Surg* 97: 111–116, 1980.
9. Skinner HB, Davis CM, Shackelford JF, Lin HJ: Evaluation of a commercial, porous stainless steel as a prosthetic implant material. *Biomat Med Dev Artif Organs* 7: 141–146, 1979.

XIII. POROUS POLYMERS

1. Ballintyn NJ, Spector M: Porous polysulfone as an attachment vehicle for orthopedic and dental implants. *Biomat Med Dev Artif Organs* 7: 23–29, 1979.
2. Blaha JD, Insler HP, Freeman MAR, Revell PA, Todd RC: The fixation of a proximal tibial polyethylene prosthesis without cement. *J Bone Joint Surg* 64B: 326–335, 1982.
3. Bryan WJ, McCaskill BL, Tullos HS: Hip endoprosthesis stabilization with a porous low modulus stem coating: factors influencing stabilization. *Clin Orthop* 157: 125–132, 1981.
4. Cestero HJ, Salyer KE, Toranto I: Bone growth into porous carbon, polyethylene, and polypropylene prostheses. *J Biomed Mater Res Symp* 6: 1–7, 1975.
5. Friedenberg ZB, Simon WH: Bone growth in Teflon sponge. *Surg Gynecol Obstet* 116: 588–592, 1963.
6. Greenberg AR, Kamel IL, Dubin S, Miller A: Notes stimulation of bone formation by a swelling endosseous implant. *J Biomed Mater Res* 12: 929–933, 1978.
7. Halstead A, Jones CW, Rawlings RD: A study of the reaction of human tissue to Proplast. *J Biomed Mater Res* 13: 121–134, 1979.
8. Homsy CA: Comments on "Characteristics of Tissue Growth into Proplast and Porous Polyethylene Implants in Bone." *J Biomed Mater Res* 13: 987–990, 1979.
9. Homsy CA: Some mechanical aspects of methyl methacrylate prosthesis seating compound. In: *The Hip*. (Proc. Hip. Society.) St. Louis, MO: CV Mosby, 1973 ch. 13, pp 156–163.
10. Homsy CA: Implant stabilization-chemical and biomechanical consideration. *Orthop Clin NA* 4: 295–311, 1973.
11. Homsy CA, Anderson MS: Functional stabilisation of prostheses with a porous low modulus materials system. In: *Biocompatibility of Implant Materials*, Williams DF (ed.). London: Sector Publications, 1976, chapt 10, pp 85–92.
12. Homsy CA, Cain TE, Kessler FB, Anderson MS, King JW: Porous implant systems for prosthesis stabilization. *Clin Orthop* 89: 220–235, 1972.
13. Howe DF, Svare CW, Tock RW: Some effects of pore diameter on single pore bony ingression pat-

terns in Teflon. *J Biomed Mater Res* 8: 399–406, 1974.

14. Klawitter JJ, Bagwell JG, Weinstein AM, Sauer BW, Pruitt JR: An evaluation of bone growth into porous high density polyethylene. *J Biomed Mater Res* 10: 311–323, 1976.
15. Klawitter JJ, Weinstein AM: The status of porous materials to obtain direct skeletal attachment by tissue ingrowth. *Acta Orthop Belg* 40: 755–765, 1974.
16. Muhr G., Stockhusen H, Muller O: Die Hueftarthoplastik mit isoelastischen Totalprothesesn im Tierexperiment. *Arch Orthop Unfall-Chir* 86: 115–128, 1976.
17. Murray DG, Dow JS: An ultrastructural study of the biocompatibility of poly (2-hydroxyethyl methacrylate) in bone. *J Biomed Mater Res* 9: 99–707, 1975.
18. Nathanson D, Gettleman L, Schnitman P, Shklar G: Histologic response to porous PMMA implant material. *J Biomed Mater Res* 12: 13–33, 1978.
19. Rhinelander FW: A flexible composite as a coating for metallic implants: microvascular and histological studies. Proplast for low modulus fixation of prostheses. *Int Orthop* (SICOT) 1: 77–86, 1977.
20. Rhinelander FW, Nelson CL: Experimental implantation of porous material into bone. *Acta Orthop Belg* 40: 771–798, 1974.
21. Rhinelander FW, Stewart CL, Wilson JW, Homsy CA, Prewitt JM: Growth of tissue into a porous, low modulus coating on intramedullary nails: An experimental study. *Clin Orthop* 164: 293–305, 1982.
22. Rijke AM, Jesser WR, Deck JD, Wright EM, Jr.: Tissue ingrowth in porous acrylic cement. *J Bioeng* 2: 333–339, 1978.
23. Rijke AM, Reiger MR, McLaughlin RE, McCoy S: Porous acrylic cement. *J Biomed Mater Res* 11: 373–394, 1977.
24. Sadr B, Arden GP: A comparison of the stability of Proplast-coated and cemented Thompson prostheses in the treatment of subcapital femoral fractures. *Injury* 8: 234–237, 1977.
25. Sauer BW, Weinstein AM, Klawitter JJ, Hulbert SF, Leonard RD, Bagwell JG: The role of porous polymeric materials in prosthesis attachment. *J Biomed Mater Res Symp* 5: 145–153, 1974.
26. Skinner AB, Schackelford JP, Lin HJ, Cutler AD: Tensile strength of bone (bone/porous polyethylene) interface. *Biomat Med Dev Artif Organs* 7: 133–139, 1979.
27. Spector M, Wigger WB, Buse MG: Radionuclide bone imaging of femoral prostheses with porous coatings. *Clin Orthop* 160: 242–249, 1981.
28. Spector M: Reply to Comments on "Characteristics of Tissue Growth into Proplast and Porous Polyethylene Implants in Bone." *J Biomed Mater Res* 13: 991–992, 1979.
29. Spector M, Harmon SL, Kreutner A: Characteristics of tissue growth into Proplast and porous polyethylene implants in bone. *J Biomed Mater Res* 13: 667–692, 1979.
30. Spector M, Michno MJ, Smarook WH, Kwiatkowski GT: A high modulus polymer for porous orthopaedic implants: biomechanical compatibility of porous implants. *J Biomed Mater Res* 12: 665–677, 1978.
31. Spector M, Flemming WR, Kreutner A, Sauer BW: Bone growth into porous high-density polyethylene. *J Biomed Mater Res Symp* 7: 595–603, 1976.
32. Spector M, Flemming WR, Sauer BW: Early tissue infiltrate in porous polyethylene implants into bone: a scanning-electron microscope study. *J Biomed Mater Res* 9: 537–542, 1975.
33. Sullivan B, Homsy CA, Woods GW, Tullos HS: Stabilization of Thompson femoral head prosthesis with a porous stem coating—A case report. *Clin Orthop* 132: 136–139, 1978.
34. Taylor DF, Smith FB: Porous methyl methacrylate as an implant material. *J Biomed Mater Res Symp* 2: 467–479, 1972.
35. Taylor GR, Warren T, Murray DG, Prins W: Bone tolerance to poly (2-hydroxyethyl methacrylate): A self-locking implant. *J Surg Res* 11: 401–409, 1971.
36. Ypma JFAM: Strength and ingrowth aspects of porous acrylic bone cement. An experimental study of possible applications of porous acrylic bone cement in total hip replacement. Nijmegen, The Netherlands: Krisp Repro Meppel, 1981. (Ph. D. thesis.)

XIV. CLINICAL EXPERIENCES WITH CEMENTLESS FIXATION

A. Ceramics

1. Boutin P: Arthroplastie totale de la hanche par prosthese en alumine. *Acta Orthop Belg* 40: 744–754, 1974.
2. Boutin P: Arthroplastie totale de la hanche par prosthese en alumina frittee. Etude experimentale et premieres applications cliniques. *Rev Chir* 58: 229–246, 1972.

3. Chiari K, Zweymuller K, Patrinieri M, Trentani C, Stark N: Eine keramische Huefttotalendoprothese zur zementfreien Implantation. *Arch Orthop Unfall-Chir* 89: 305–313, 1977.
4. Griss P, Heimke G: Five years experience with ceramic-metal-composite hip endoprostheses. I. Clinical evaluation. *Arch Orthop Traumat Surg* 98: 157–164, 1981.
5. Griss P, Werner E, Buchinger R, Heimke G: Die Mannheimer Oxidkeramik-Metall-Verbundendoprothesen. Eine kritische Wertung unserer bisherigen klinischen Erfahrungen. *Arch Orthop Unfall-Chir* 87: 73–84, 1977.
6. Heimke G, Griss P, Jentschura G, Werner E: Direct anchorage of Al_2O_3 ceramic hip components: Three years of clinical experience and results of further animal studies. *J Biomed Mater Res* 12: 57–65, 1978.
7. Knahr K, Salzer M, Plenk, Jr. H, Grundschober F, Ramach W: Experience with bioceramic implants in orthopaedic surgery. *Biomaterials* 2: 98–104, 1981.
8. Mittelmeier H, Harms J: Huftalloplastik mit Keramik-Endoprothesen bei traumatischen Huftschaden. *Unfallheilk* 82: 67–75, 1979.
9. Mittelmeier H, Harms J: Derzeitiger Stand der zementfreien Veraenkerung von Keramik-Metall-Verbundprothesen. *Z Orthop* 117: 478–481, 1979.
10. Motta A, Callea C, Roncaglia L: Total prostheses without cement in osteoarthritis of the hip joint. *Ital J Orthop Traumat* 5: 65–72, 1979.
11. Plenk, Jr. H, Salzer M, Locke H, Stark N, Punzet G, Zweymuller K: Extracortical attachment of bioceramic endoprostheses to long bones without bone cement. *Clin Orthop* 132: 252–265, 1978.
12. Rossak K, Brinkmann KE: Erste Erfahrungen mit einer zementlos zu veraenkernden Keramikprothese zur Austauchoperation ausgelockerter Totalendoprothesen. *Z Orthop* 115: 290–299, 1977.

B. Metals

1. Cameron HU: The results of early clinical trials with a microporous coated metal hip prosthesis. *Clin Orthop* 165: 188–190, 1982.
2. Cameron HU, Macnab I, Pilliar RM: A porous metal system for joint replacement surgery. *Int J Artif Organs* 1: 104–109, 1978.
3. Judet R, Siguier M, Brumpt B, Judet T: A noncemented total hip prosthesis. *Clin Orthop* 137: 76–84, 1978.
4. Lord GA, Hardy JR, Kummer FJ: An uncemented total hip replacement. Experimental study and review of 300 Madreporique arthroplasties. *Clin Orthop* 141: 2–16, 1979.
5. Rayan GM, Brooker, Jr. AF: Porous-coated endoprosthesis in treatment of subcapital fractures. *Orthopedics* 3: 660–666, 1980.

C. Polymers

1. Blaha JD, Insler HP, Freeman MAR, Revell PA, Todd RC: The fixation of a proximal tibial polyethylene prosthesis without cement. *J Bone Joint Surg* 64B: 326–335, 1982.
2. Halstead A, Jones CW, Rawlings RD: A study of the reaction of human tissue to Proplast. *J Biomed Mater Res* 13: 121–134, 1979.
3. Morscher EW, Dick W, Kerner V: Cementless fixation of polyethylene acetabular component in total hip arthroplasty. *Arch Orthop Traumat Surg* 99: 223–280, 1982.
4. Morscher E, Mathys R: Erste Erfahrungen mit einer zementlosen isoelastischen Totalprothese der Huefte. *Z Orthop* 113: 745–749, 1975.
5. Morscher E, Bombelli R, Schenk R, Mathys R: The treatment of femoral neck fractures with an isoelastic endoprosthesis implanted without bone cement. *Arch Orthop Traumat Surg* 98: 93–100, 1981.
6. Sadr B, Arden GP: A comparison of the stability of Proplast-coated and cemented Thompson prostheses in the treatment of subcapital femoral fractures. *Injury* 8: 234–237, 1977.
7. Sullivan B, Homsy CA, Woods GW, Tullos HS: Stabilization of Thompson femoral head prosthesis with a porous stem coating—a case report. *Clin Orthop* 132: 136–139, 1978.

XV. TECHNIQUES FOR EVALUATING THE INTERFACE

A. General

1. Albrektsson T, Linder L: A method for short- and long-term *in vivo* study of the bone-implant interface. *Clin Orthop* 159: 269–273, 1981.
2. Blencke BA, Broemer H, Deutscher K: Glaskeramik, ein neuer bioaktiver Implantatwerkstoff. *Z Med Orthop Technol* 6: 144–148, 1975.
3. Dustoor MR: Porous 316L stainless steel canine hip prostheses. University of Wisconsin, 1977. (PhD thesis.)

4. Eulenberger J, Stich H, Niederer PG: Biokeramik im Rattenversuch (Vorlaufige Mitteilung). *Schweiz Mschr Zahnheilk* 88: 378–388, 1978.
5. Gross UM, Strunz V: Surface staining of sawed sections of undecalcified bone containing alloplastic implants. *Stain Technol* 52: 217–219, 1977.
6. Johnstone JC, Tam CS: An improved histological method for undecalcified bone sections. *Med Lab Technol* 30: 355–359, 1973.
7. Karnovsky MJ: A formaldehyde-gluteraldehyde-fixative of high osmality for use in electron microscopy. *J Cell Biol* 37A: 27, 1965.
8. Klawitter JJ, Hulbert SF: Application of porous ceramics for the attachment of load bearing internal orthopaedic applications. *J Biomed Mater Res Symp* 2: pt. I, 161–229, 1971.
9. Klawitter JJ: Research techniques in biomaterials evaluation. *Workshop I—Bioevaluation of hard material implants*. Clemson University, SC, 1971.
10. McQueen CM, Monk IB, Horton PW, Smith DA: Preparation of undecalcified bone sections for auto- and microradiography. *Calc Tiss Res* 10: 23–30, 1972.
11. O'Keefe P: A technique for preparing thin sections of porous-metal coated metallic implants to show bone ingrowth. In: *Microstructural Science*, Filer EW, Hoegfeldt JM, McCall J (eds.). New York: Elsevier 1976, vol 4, pp 169–177.
12. Page KM: Bone and the preparation of bone sections. In: *Theory and Practice of Histological Techniques*. Bancroft JD, Stevens A (eds.). New York: Churchill Livingstone, 1977, ch. 15, pp 223–248.
13. Pugh JW, Rose RM, Radin EL: Techniques for the study of the structure of bone. *Microstructures* 3: 23–27, 1972.
14. Smith LG, Karagianes MT: Histological preparation of bone to study ingrowth into implanted materials. *Calc Tiss Res* 14: 333–337, 1974.
15. Steflik DE, McKinney RV Jr., Mobley GL, Koth DL: Simultaneous histological preparation of bone, soft tissue and implanted biomaterials for light microscopic observations. *Stain Technol* 57: 91–98, 1982.
16. Watts RH, Green D, Howells GR: Improvements in histological techniques for epoxy-resin embedded bone specimens. *Stain Technol* 56: 155–161, 1981.
17. Xipell J, Makin H, McKinnon P: A method for the preparation of undecalcified bone sections for light microscopy and microradiography. *Stain Technol* 49: 69–76, 1974.

B. Sectioning

1. Blencke BA: Erfahrungen mit dem Leitz-Sagemikrotom (Experiences with the Leitz Sawing Microtome). *Leitz-Mitt, Wiss U Tech* 6: 198–200, 1975.
2. Brown SA, Simpson J: Electrochemical dissolution of metallic implants prior to histologic sectioning. *J Biomed Mater Res* 13: 337–338, 1979.
3. Friend JV, Smith GS: A rapid method of preparing thin (7 micron) calcified tooth sections. *J Med Lab Technol* 21: 51–56, 1964.
4. Frost HM: Staining of fresh, undecalcified, thin bone sections. *Stain Technol* 34: 135–146, 1959.
5. Frost HM: Preparation of thin, undecalcified bone sections by rapid manual method. *Stain Technol* 33: 273–376, 1958.
6. Gilbertson EMM: A method of preparation of undecalcified bone sections. *Med Lab Sci* 34: 89–91, 1977.
7. Gore LF, Abbott JJ: The sectioning of undecalcified tissues using a diamond impregnated cutting disc. *J Med Lab Technol* 21: 293–297, 1964.
8. Hart BL, Lane J, Watkins G, Ralis ZA: A technique for cutting slices from femoral heads and other awkwardly shaped bones. *Calcif Tiss Int* 34: 29–30, 1982.
9. Hill BD: A technique for the sectioning of mineralized bone. *Aust J Med Technol* 4: 9–11, 1973.
10. Jowsey J: The use of the milling machine for preparing bone sections for microradiography and microautoradiography. *J Sci Instrum* 32: 159–163, 1955.
11. Seliger WG: The production of large, epoxy-embedded, 50 U sections by precision sawing; a preliminary to survey for ultrathin sectioning. *Stain Technol* 43: 269–272, 1968.
12. Sognnaes RF: Preparation of thin "serial" ground sections of whole teeth and jaws and other highly calcified and brittle structures. *Anat Rec* 99: 133–144, 1947.
13. Stuermer KM: Vollautomatische Herstellung von Knochenschliffen bei exacter Dickeneinstellung. *Acta Anat* 103: 100–108, 1979.
14. Wright TM, Hughes PW, Torzilli PA, Wilson PD, Jr.: A method for the postmortem evaluation of an

in-situ total hip replacement. *J Bone Joint Surg* 61A: 661–668, 1979.

C. Embedding

1. Anon: Embedding specimens in methacrylate resins. Pamphlet No. CM-102 L/ci. Philadelphia, PA: Rohm and Haas.
2. Difford J: A simplified method for the preparation of methyl methacrylate embedding medium for undecalcified bone. *Med Lab Technol* 31: 79–81, 1974.
3. Gore LF, Milford D, Ferguson HW: Methacrylate embedding of undecalcified tissues for subsequent microradiography. *Med Lab Sci* 33: 305–307, 1976.
4. Kenner GH, Henricks L, Gimenez G, Barb W, Park JB: Bone embedding technique with inhibited PMMA monomer. *Stain Technol* 57: 121–126, 1982.
5. Rijke AM, McCoy S, McLaughlin RE: A rapid embedding technique for the preparation of undecalcified bone and tooth section. *Am J Clin Pathol* 56: 766–768, 1971.
6. Spurr AR: A low-viscosity epoxy resin embedding medium for electron microscopy. *J Ultrastr Res* 26: 31–43, 1969.

D. Microradiography/Microangiography

1. Bergendahl G, Engfeldt B: Preparing material for microradiography. *Acta Pathologica* 49: 30–38, 1960.
2. Bowes DN, Dunn EJ: A simple vacuum cassette for microradiography. *Stain Technol* 50: 355–357, 1975.
3. Dunn EJ, Bowes DN, Rothert SW, Greer, III RB: Microradiography of undecalcified bone: a simplified, relatively inexpensive technique. *Johns Hopkins Med J* 135: 106–113, 1974.
4. Dunn EJ, Bowes DN, Rothert SW, Greer, III RB: An inexpensive x-ray source for the microradiography of bone. *Calc Tiss Res* 15: 329–332, 1974.
5. Jowsey J, Kelly PJ, Riggs BL, Bianco AJ, Jr., Scholz DA, Gershon-Cohen J: Quantitative microradiographic studies of normal and osteoporotic bone. *J Bone Joint Surg* 37A: 785–872, 1965.
6. Jowsey J, Riggs BL: Assessment of bone turnover by microradiography and autoradiography. *Sem Nucl Med* 2: 3–17, 1972.
7. Rhinelander FW, Stewart CL, Wilson JW: Bone vascular supply. In: *Skeletal Research: An Experimental Approach*. Simmons DJ, Kunin AS (eds.). NY Academic, 1979, ch. 16, pp 367–395.
8. Rhinelander FW, Baragry RA: Microangiography in bone healing. *J Bone Joint Surg* 44A: 1273–1298, 1962.
9. Vanderhoeft PJ, Peterson LFA, Kelly PJ: A method for correlative analysis of microradiogram and tetracycline fluorophase of puppies' bone. *Proc Mayo Clin* 229–235, 1962.

E. Fluorochrome Labeling

1. Frost HM: Tetracycline-based histological analysis of bone remodeling. *Calcif Tiss Res* 3: 211–237, 1969.
2. Frost HM: Measurement of human bone formation of means of tetracycline labeling. *Can J Biochem Physiol* 4: 31, 1963.
3. Frost HM, Villanueva AR, Roth H: Tetracycline staining of newly forming bone and mineralizing cartilage *in vivo*. *Stain Technol* 35: 135–138, 1960.
4. Frost HM, Villaneuva AR, Roth H: Measurement of bone formation in a 57-year old man by means of tetracycline. *Henry Ford Hospital Bull* 8: 239–254, 1960.
5. Hansson KI: Daily growth in length of diaphysis measured by oxytetracycline in rabbit normally and after medullary plugging. *Acta Orthop Scand* supp. 101, 1967.
6. Harris WH: A microscopic method of determining rates of bone growth. *Nature* 188: 1038–1039, 1960.
7. Harris WH, Haywood EA, Lavorgna J, Hamblen DL: Spatial and temporal variations in cortical bone formation in dogs. *J Bone Joint Surg* 50A: 1118–1128, 1968.
8. Harris WH, Jackson RH, Jowsey J: The *in vivo* distribution of tetracyclines in canine bone. *J Bone Joint Surg* 44A: 1308–1320, 1962.
9. Harris WH, Travis DF, Fiberg U, Radin EL: The *in vivo* inhibition of bone formation by alizarin red S. *J Bone Joint Surg* 46A: 493–508, 1964.
10. Milch RA, Rall DP, Tobie JE: Bone localization of the tetracyclines. *J Nat Cancer Inst* 19: 87–93, 1957.

11. Modis L, Petko M, Foldes I: Histochemical examination of supporting tissues by means of fluorescence. II. Fluorochromes as an indicator of lamellar bone mineralization. *Acta Morph Acad Sci Hung* 17: 157–166, 1969.
12. Olerud S, Lorenzi GL: Triple fluorochrome labeling in bone formation and bone resorption. *J Bone Joint Surg* 52A: 274–278, 1970.
13. Rahn BA: Polychrome fluorescence labeling of bone formation. Instrumental aspects and experimental use. *Zeiss Inform* 22: 36–39, 1977.
14. Rahn BA, Perren SM: Xylenol orange, a fluorochrome useful in polychrome sequential labeling of calcifying tissues. *Stain Technol* 46: 125–129, 1971.
15. Rahn BA, Perren SM: Calcein blue as a fluorescent label in bone. *Experientia* 26: 519–520, 1970.
16. Rahn BA, Fleisch H, Moor R, Perren SM: The effect of fluorescent labels on bone growth and calcification in tissue culture. *Eur Surg Res* 2: 137–138, 1970.
17. Raman A: Appositional growth rate in rat bones using the tetracycline labelling method. *Acta Orthop Scand* 40: 193–197, 1969.
18. Stroemqvist B, Ceder L, Hansson LI, Thorngren KG: Vitality of the femoral head after femoral neck fracture evaluated by tetracycline staining. *Arch Orthop Traumat Surg* 99: 1–6, 1981.
19. Suzuki HO, Matthews A: Two-color fluorescent labeling of mineralizing tissues with tetracycline and 2,4-bis [N N′-di (carbomethyl)aminomethyl]fluorescein. *Stain Technol* 41: 57–60, 1966.
20. Treharne RW, Brighton CT: The use and possible misuse of tetracycline as a vital stain. *Clin Orthop* 140: 240–246, 1979.
21. Vanderhoeft PJ, Kelly PJ, Peterson FA: Determination of growth rates in canine bones by means of tetracycline-labeled patterns. *Lab Invest* 11: 714–726, 1962.

F. Bone Histomorphometry

1. Jee WSS, Parfitt AM (eds.). *Bone Histomorphometry–3nd Int Workshop, Sun Valley, 1980*. Paris, France: Societe Nouvelle de Publications Medicales et Dentaires, 1981.
2. Meunier PJ (ed.). *Bone Histomorphometry–2nd Int Workshop, Lyon, 1976*. Toulouse, France: Societé de la Nouvelle Imprimerie Fournie, 1977.
3. Jaworski, ZFG (ed.). *Proceedings of the First Workshop on Bone Morphometry*. Ottawa, Canada: University of Ottawa Press, 1973.

XVI. MISCELLANEOUS

A. General References

1. Andrade JR: Interfacial phenomena and biomaterials. *J Assoc Adv Med Instrum* 7: 110–120, 1973.
2. Coleman DL, King RN, Andrade JD: The foreign body reaction–An experimental protocol. *J Biomed Mater Res Symp* 5: 65–76, 1974.
3. Hedley AK: Present state, problems, and future implications of porous-coated implants. In: *The Hip*. (Proc. Hip Society.) St. Louis, MO: CV Mosby, 1980, ch. 16, pp 329–342.
4. Hench LL: Special report: The interfacial behavior of biomaterials, 1979. *J Biomed Mater Res Symp* 14: 803–811, 1980.
5. Hulbert SF, Cooke FW, Klawitter JJ, Leonard RB, Sauer BW, Moyle DD, Skinner HB: Attachment of prostheses to the musculoskeletal system by tissue ingrowth and mechanical interlocking. *J Biomed Mater Res Symp* 4: 1–23, 1973.
6. Moyle DD, Klawitter JJ, Hulbert SF: Mechanical properties of the bone-porous biomaterial interface: elastic behavior. *J Biomed Mater Res Symp* 4: 363–382, 1973.
7. Williams D: Step nearer the redundant implant. *New Scientist* 58: 221–223, 1973.
8. Winter GD: Prostheses and tissue: The interface problem. *Biomed Eng* 8: 390–394, 1973.

B. Bibliography

1. Black J (ed.). Biological performance of materials: Fundamentals of biocompatibility. In: *Biomedical Engineering and Instrumentation*. Dekker, 1981, vol. 8.
2. Gschwend N, Debrunner HU (eds.): *Total Hip Prosthesis*. Baltimore, MD: Williams & Wilkins, 1976.
3. Hastings GW, Williams DF (eds.): Mechanical properties of biomaterials. In: *Advances in Biomaterials*. Chichester, UK: Wiley, 1980, vol 2.
4. Hench LL, Ethridge EC: *Biomaterials. An Interfacial Approach*. New York: Academic, 1983.
5. Lee AJC, Albrektsson T (eds.): Clinical applications of biomaterials. In: *Advances in Biomaterials*, Chichester, UK: Wiley, 1982, vol. 4.
6. Oonishi H, Oo Y (eds.): *Orthopaedic Ceramic Implants*. Osaka: Japan Society Orthopedic Cerarmic Implants, 1981, vol 1.
7. Oest O, Muller K, Hupfauer W: Die Knochen-

zemente. Stuttgart, Federal Republic of Germany: Enke Ferdinand, 1975.

8. Orthopaedic Research Society: *Transactions of the Annual Meetings of the Orthopaedic Research Society, 1976–1983*, vols. 1–8.
9. Schaldach M, Hohmann D (eds.): *Advances in Artificial Hip and Knee Joint Technology*. New York: Springer, 1976.
10. Sevitt S: *Bone Repair and Fracture Healing in Man*. Edinburgh: Churchill Livingstone, 1982.
11. Society for Biomaterials: *Transactions of the Annual Meetings of the Society for Biomaterials, 1977–1983*, vols. 1–6.
12. Williams DF (ed.): *Biocompatibility of Orthopaedic Implants*. Boca Raton, FL: CRC Press, 1982, vols. 1,2. (CRC Series in Biocompatibility.)
13. Williams DF (ed.): *Biocompatibility of Clinical Implant Materials*. Boca Raton, FL: CRC Press, 1982, vol. 1. (CRC Series in Biocompatibility.)
14. Williams DF (ed.): *Biocompatibility of Implant Materials*. London: Sector, 1976.
15. Winter GD, Gibbons DF, Plenk H, Jr. (eds.): Biomaterials. In: *Advances in Biomaterials*. Chichester, UK: Wiley, 1982, vol. 3.
16. Winter GD, Leray JL, de Groot K (eds.): Evaluation of biomaterials. *In: Advances in Biomaterials*. Chichester, UK: Wiley, 1980, vol 1.
17. Zweymueller K: Knochen- Und Gelenkersatz mit Biokeramischen Endoprothesen. Vienna, Austria: Facultas, 1978.