On the History of Bioceramics for Hip Joint Replacements

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Summary

- The Precursors
- 1970s : The Pioneers
- 1980 – 2004: The Development
  - Alumina
  - Zirconia
  - ZTA – ATZ composites
- Bioceramics in Hip Joint Replacements Today

Summary

The Precursors

1970s : The Pioneers

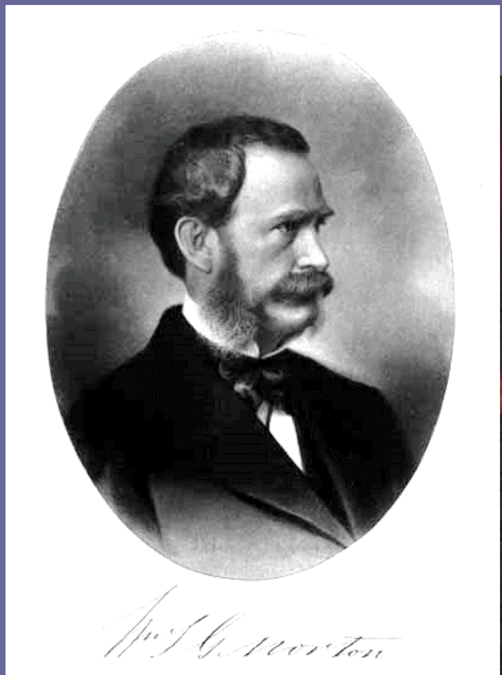
1980 – 2004: The Development

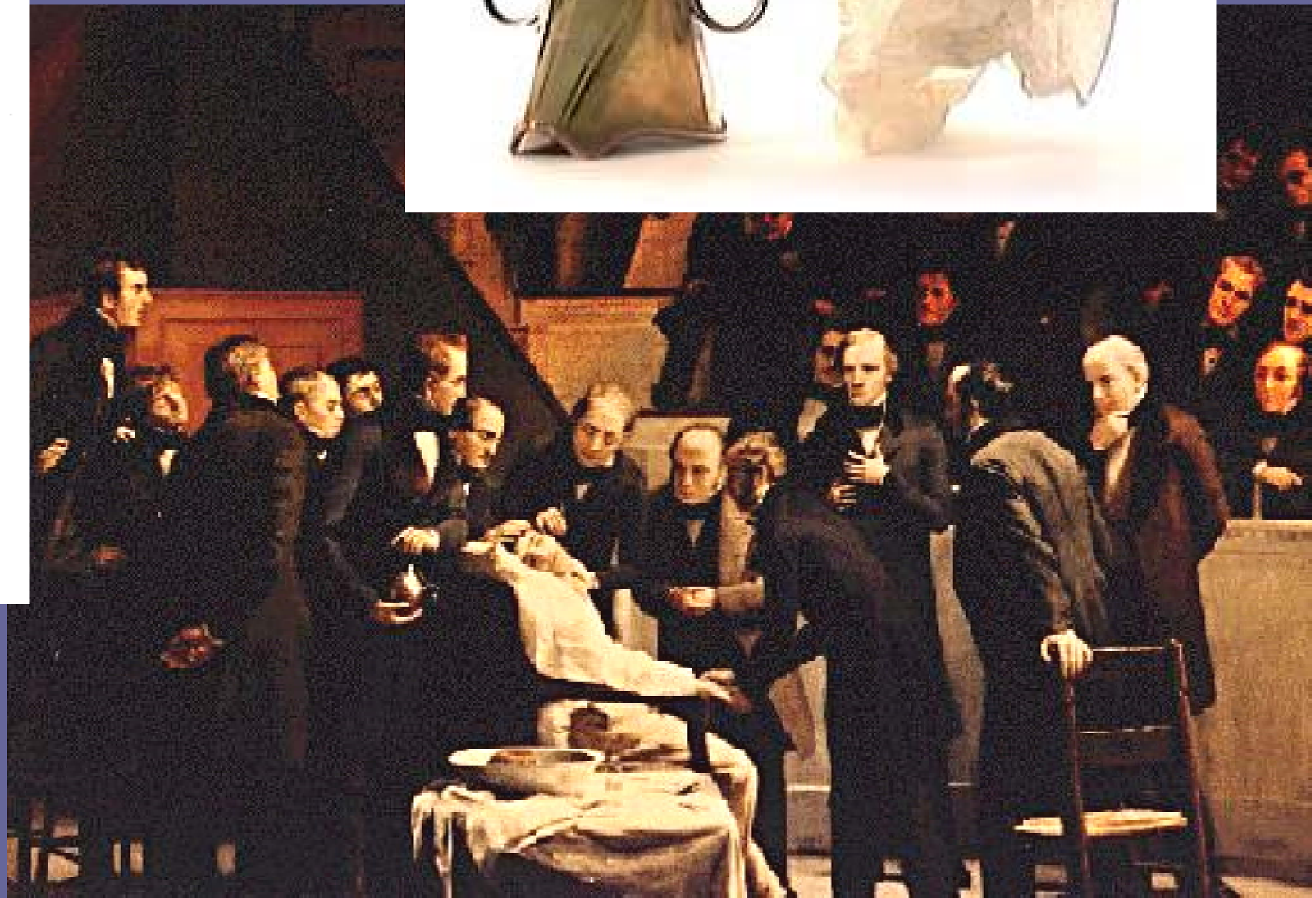
- Alumina
- Zirconia
- ZTA – ATZ composites

Bioceramics in Hip Joint Replacements Today

Morton, 1846

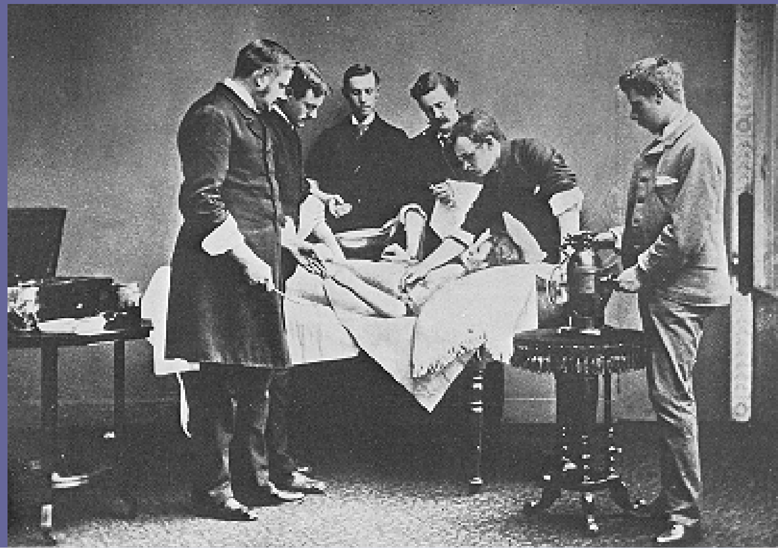
Anesthesia





Pasteur, 1862
Sterilization

Lister, 1867
Antisepsis



Karl Joseph Bayer

Alumina US Patent, 1894

UNITED STATES PATENT OFFICE.

KARL JOSEPH BAYER, OF ELABUGA, RUSSIA.

PROCESS OF MAKING ALUMINA.

SPECIFICATION forming part of Letters Patent No. 515,895, dated March 6, 1894.

Application filed October 3, 1892. Serial No. 447,691. (No specimens.)

To all whom it may concern:

Be it known that I, KARL JOSEPH BAYER, a subject of the Emperor of Austria-Hungary, residing at Elabuga, in the government of Wiatka and Empire of Russia, have invented certain new and useful Improvements in Processes of Obtaining Alumina; and I do declare the following to be a full, clear, and exact description of the invention.

In the Letters Patent No. 382,505, granted to me heretofore under date of May 8, 1888, for a process of obtaining alumina, aluminate-lyes were decomposed by the action of hydrate of alumina and thereby alumina-lyes obtained in which the proportion of the molecules of alumina (Al_2O_3) and that of soda (Na_2O) was one to six. These lyes were concentrated, mixed with bauxite and subjected to the heat of suitable calcining-furnaces for the purpose of obtaining crude aluminate, which is then dissolved in water, filtered and then again subjected to decomposition.

A number of experiments have shown that in many cases the decomposed and concentrated aluminate-lyes act in the nature of caustic soda. I found that when the decomposed lyes are concentrated to a density of from 40 to 44° Baumé, they will dissolve the alumina directly from the bauxite, provided that said lyes are subjected with the same to continuous agitation at a pressure of from three to four atmospheres, from one and one-half to two hours, at a temperature of from 160° to 170° centigrade. The bauxite is finely pulverized, and if only a small quantity of silicic acid is present in the same, the alumina will be dissolved to such an extent that only traces of the same remain, that is to say, up to a small quantity, which forms with the dissolved silicic acid and a corresponding quantity of soda the well known double salt $Na_2OAl_2O_3,3SiO_2 9$ aq.

In the ordinary red French bauxite, which is usually used in the manufacture of alumina and which contains about sixty-one per centum of alumina (Al_2O_3) and about three per centum of silicic acid (SiO_2), fifty-nine per centum of the alumina are obtained in solution when the aluminate-lye and the bauxite are mixed in such a proportion that after the reaction the molecular proportion of the resulting solution is as follows:— $Al_2O_3 : Na_2O = 1 : 1.75$ or $1 : 1.85$, which corresponds to a yield of at least ninety-six per centum of the alumina contained in the raw material. The apparatus that is used for this purpose consists of a cylindrical boiler that is made of boiler iron one-half inch in thickness, which boiler is provided with the usual accessories, such as a safety-valve, an agitating-device, a pressure-gage, a pressure-pipe and filling-opening. As will be readily apparent, the boiler can be made comparatively small in dimensions, which fact precludes any danger in the use of the same. At the same time, the consumption of fuel and the labor required for charging the apparatus are comparatively small and insignificant.

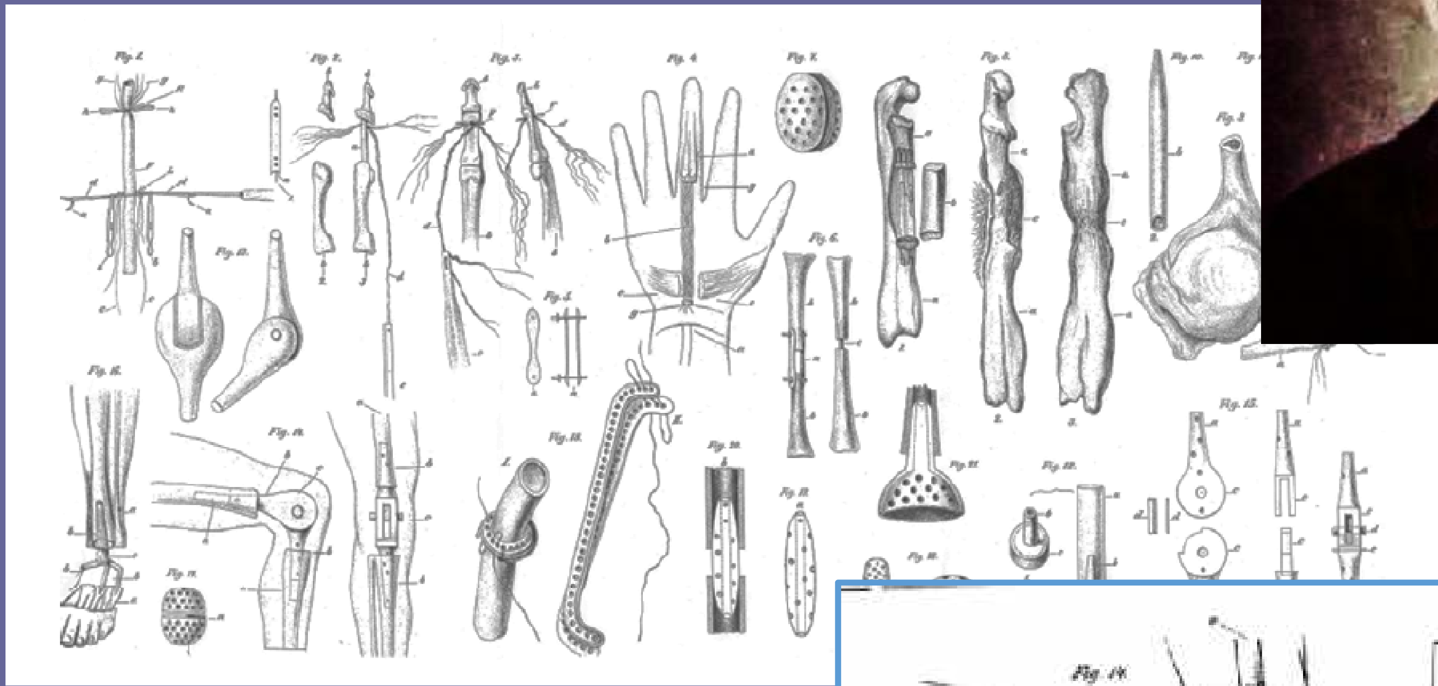
In a boiler of eight feet length and three feet in diameter can be treated from eight thousand to ten thousand pounds of bauxite per day, and the consumption of fuel and labor required is hardly one-fifteenth of the expense connected with that required for the corresponding number of calcining-furnaces heretofore in use, aside from the fact that by my present process the alumina is obtained in solution, while by my prior process the dry, crude aluminate as it comes from the calcining-furnace has to be dissolved for use. The red residue which remains in the boiler after treatment of the bauxite and which contains iron, forms a sediment at the bottom of the boiler and can be readily subjected to filtration and washing. As the residue contains a high percentage of iron and a comparatively small percentage of alumina, it can be worked up as a bye-product, or it can be mixed with iron ore and utilized in the production of pig-iron.

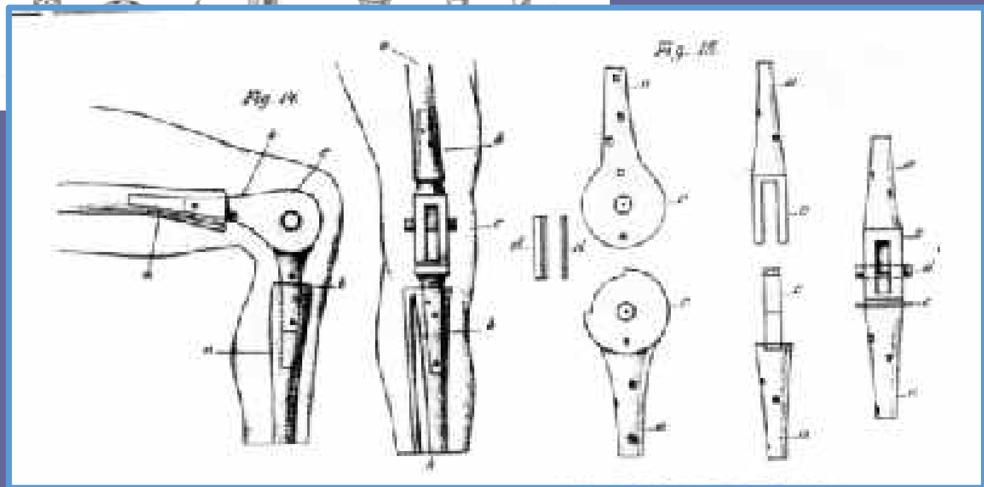
Having thus described my invention, what I claim as new, and desire to secure by Letters Patent, is—

The process herein described of producing alumina from bauxite, which consists in sub-

Themistocles Gluck

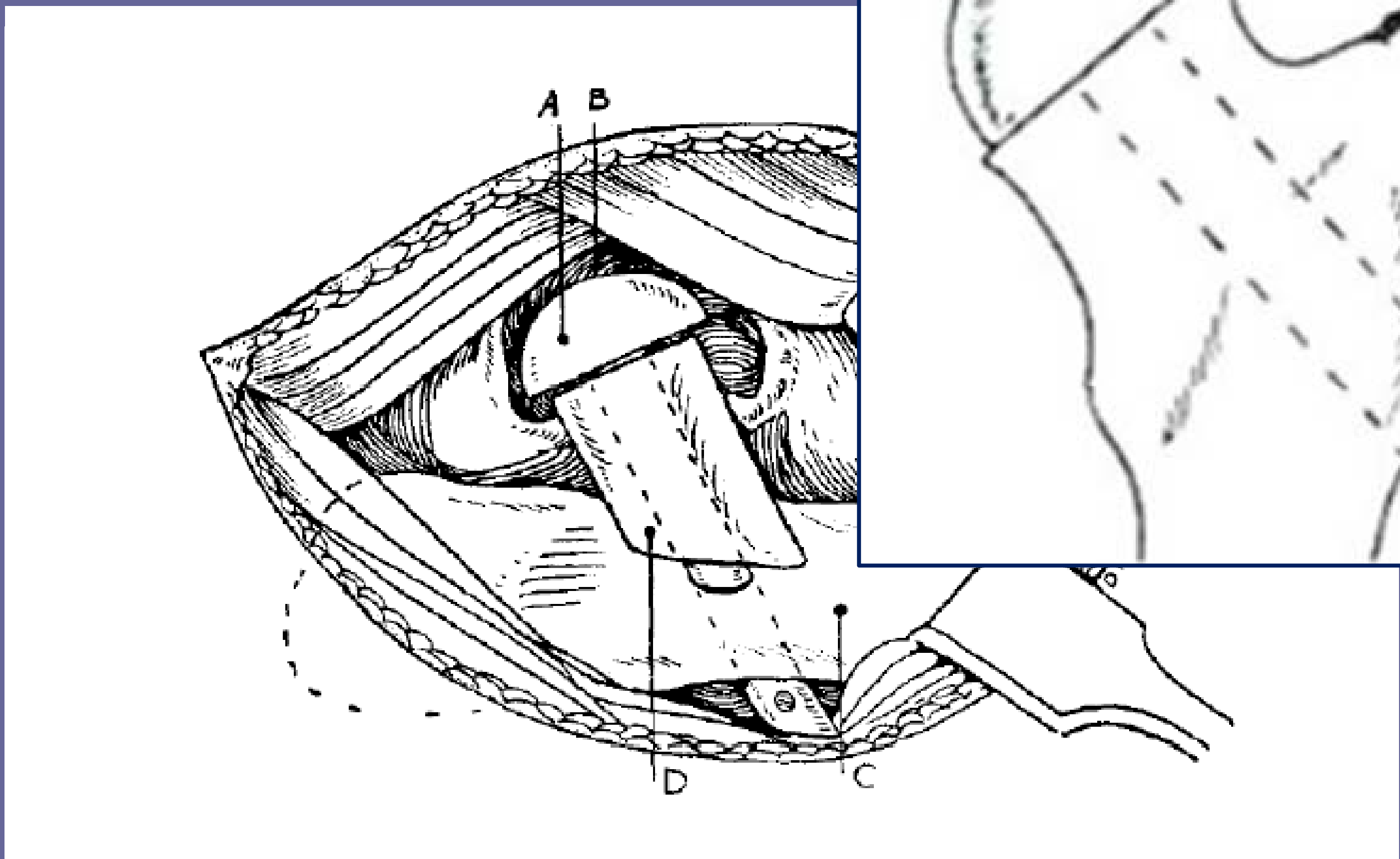
Ivory Joint Replacements,1891

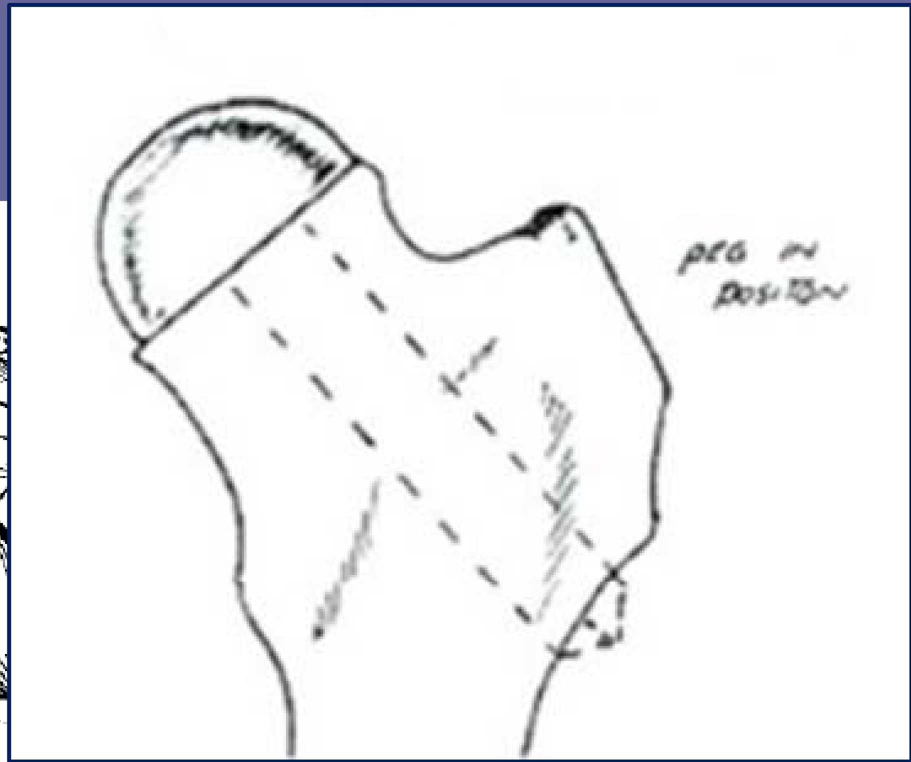




EWH Groves

Ivory Femural head replacement, 1926





Ban Saw

Ivory Hip Endoprosthesis, 1970

THE JOURNAL OF BONE AND JOINT SURGERY VOL. 52 B, NO. 1, FEBRUARY 1970

Ivory prostheses for ununited fractures of neck of femur—*Dr U. San Baw* (Mandalay, Burma) described the use of a prosthetic femoral head made of ivory. Ivory was extremely strong material, being similar to Vitallium and titanium on static compression testing. It had weak shear strength when
tested parallel to the grain and this fact had to be taken into a … eses.
The coefficient of friction of polished ivory on cartilage was … rmal
joint (0·02). The prosthesis which he used was shaped rather … mber
of the early models had fractured at the neck of the prosthesis, … duce
a thicker collar with reduced curvature between the neck and t … tion.
He had used the prostheses in 100 cases of ununited fracture … t ten
years and no adverse reaction to the ivory had been seen. Eig … good
or excellent result, based on Judet's criteria. In his country i … , and
76 per cent of his patients had regained this ability. The com … stem
of the prostheses in seven cases, five of which had been replac … ation
but had been subsequently reduced with good results. The ca … rmed
a strong bond to the ivory stem of the prosthesis, from whic … line.
Marginal erosion of the stem occurred with invasion by bo … gical
bonding. Dr San Baw presented an ivory prosthesis which … f the
Association.

Max Rock, 1933

…Aluminum Oxide…

DEUTSCHES REICH

AUSGEGEBEN AM 6. SEPTEMBER 1933

REICHSPATENTAMT

PATENTSCHRIFT

№ 583 589

KLASSE 30d GRUPPE 1 01

R 84701 IX/30d

Tag der Bekanntmachung über die Erteilung des Patents: 24. August 1933

Max Rock in Düsseldorf-Oberkassel

Künstliche Ersatzteile für das Innere und Äußere des menschlichen und tierischen Körpers

Patentiert im Deutschen Reiche vom 22. April 1932 ab

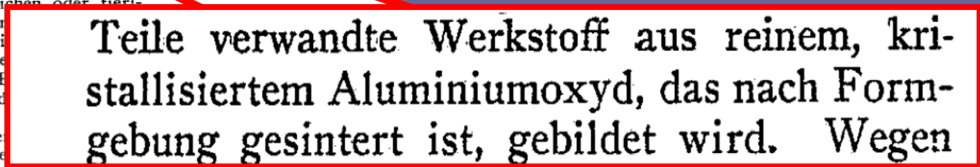
Die Erfindung bezieht sich auf künstliche Ersatzteile für das Innere und Äußere des menschlichen oder tierischen Körpers, anatomische oder panoptische Modelle o. dgl., und besteht darin, daß der zur Herstellung dieser Teile verwandte Werkstoff aus reinem, kristallisiertem Aluminiumoxyd, das nach Formgebung gesintert ist, gebildet wird. Wegen der vorzüglichen chemischen und physikalischen Eigenschaften dieses Werkstoffes wird er allen an solche Ersatzteile oder Modelle gestellten Anforderungen gerecht.

Die bisher für die künstlichen Ersatzteile von lebenden Körpern und für die Herstellung panoptischer oder anatomischer Modelle o. dgl. verwandten Werkstoffe entsprechen in der Gesamtheit der Eigenschaften nicht den an sie gestellten Anforderungen. Diese Werkstoffe unterliegen starker mechanischer Beanspruchung und chemischer Beeinflussung durch die Säfte und Sekrete des lebenden Körpers, sie müssen darum hohe Festigkeit, Formbeständigkeit, Elastizität, Undurchdringlichkeit für Flüssigkeiten und Unlöslichkeit in den Säften und Sekreten des Körpers auch bei fortgesetzter Einwirkung aufweisen und unveränderlich beständig sein. Es dürfen weder Farbe- noch Formveränderungen durch Quellen oder Schrumpfung während der fortgesetzten Beeinflussung stattfinden, die Werkstücke müssen homogen und undurchdringlich sein für Flüssigkeiten und Gase, wodurch auch eine Durchsetzung mit Infektionsstoffen vermieden wird. Sie dürfen endlich keinerlei nachteilige Einwirkungen auf die mit diesen Prothesen in Berührung stehenden Schleimhäute usw. haben und müssen auch ohne jeden Eigengeruch und Eigengeschmack sein.

Diese Erfordernisse erfüllt der aus gesintertem reinem, kristallisiertem Aluminiumoxyd [illegible] Werkstoff. Die Festigkeit und Härte [illegible] Werkstoffes aus reinem, kristallisiertem [illegible], das in bekanntem Formgebung[illegible] folgendem Sinterungsprozeß verarbe[illegible] größer als die der bisher verwand[illegible] Gold, Platin, Porzellan, Kautschuk [illegible] densations- oder Polymerisationskunststo[illegible] und gibt darum die Möglichkeit, Ersatzteile jeder Art für den menschlichen oder tierischen Körper o. dgl. zweck[illegible] len. Hierin liegt ein erhebli[illegible] die bisher für die Zwecke de[illegible] gewandten Werkstoffe den [illegible] nicht gewachsen waren und d[illegible] den Patienten unangenehme [illegible] forderlich wurden. Zu den e[illegible] schaften des Werkstoffes, de[illegible] Formgebungs- und nachfolgendem Sinterungsprozeß verarbeitet wird, kommt noch der Vorteil der verhältnismäßigen Billigkeit

German Patent 583.589

“Artificial replacement for the interior and exterior of human and animal bodies”



Teile verwandte Werkstoff aus reinem, kristallisiertem Aluminiumoxyd, das nach Formgebung gesintert ist, gebildet wird. Wegen

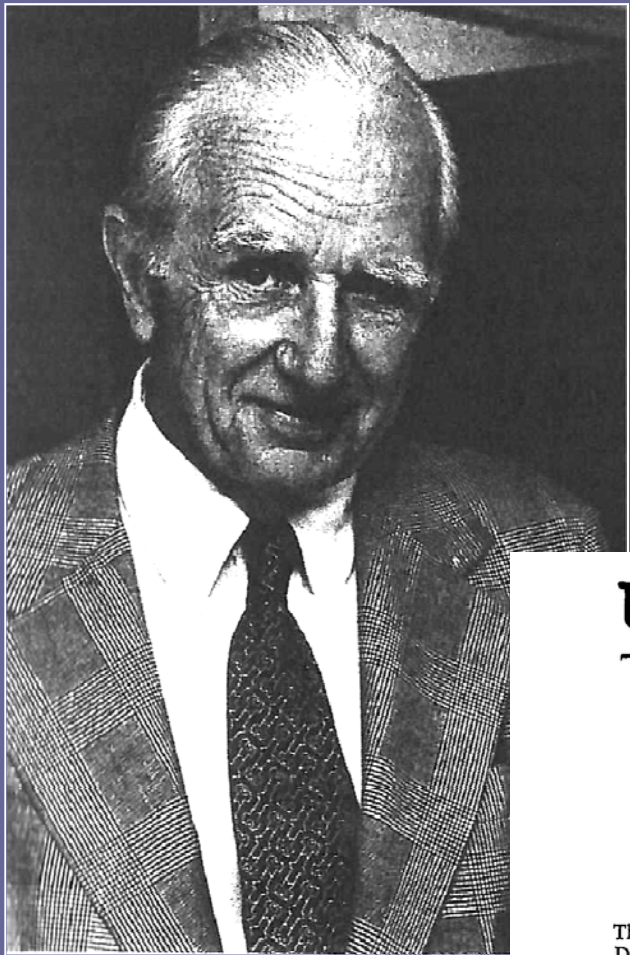
Cerosium™ (1962)

Smith W.L., M.D. , Elgin, IL
Ross, G.A. , The Haeger Potteries, Dundee, IL

52 vol%:
- 20% $MgAl_2O_4$ (spinel)
- 50% $CaAlSi_2O_8$ (anorthite)
- **28% Al_2O_3 (corundum)**
- 2% Trace minerals

\+

48 vol% - Epoxy resin



W.L. Smith

United States Patent Office 770,903
Registered June 2, 1964

PRINCIPAL REGISTER
Trademark
Ser. No. 164,970, filed Mar. 19, 1963

CEROSIUM

The Haeger Potteries, Inc. (Illinois corporation)
Dundee, Ill.

For: PROSTHETIC PARTS—NAMELY, HIP PROSTHESES AND KNEE PROSTHESES AND BONE SUBSTITUTES, AND MATERIALS FOR MAKING PROSTHETIC PARTS—NAMELY, POROUS CERAMIC IMPREGNATED WITH PLASTIC—in CLASS 44.
First use Sept. 12, 1962; in commerce Jan. 31, 1963.

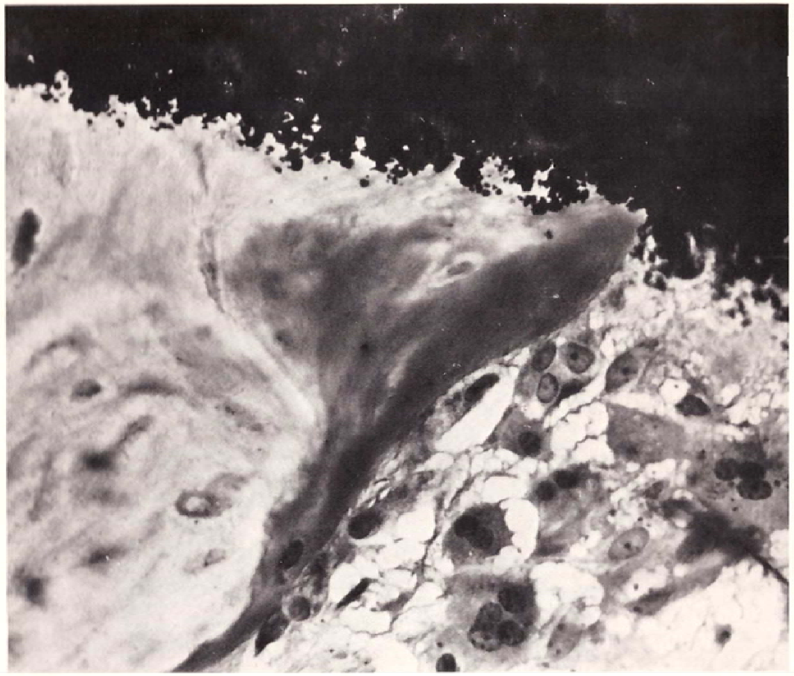
The 1st Clemson Biomaterials Symposium, 1969

…except for the several attempts to use plaster of Paris, only recently has research been reported in the literature on the use of ceramic materials for internal prosthetic applications, particularly **the repair of skeletal defects.**

Hulbert, S.F. 1969

Use of Ceramics in Surgical Implants

Edited by
Samuel F. Hulbert
and
Frank A. Young

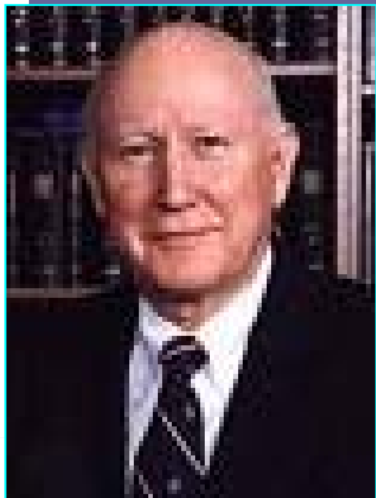


Gordon and Breach Science Publishers

USE OF CERAMICS IN SURGICAL IMPLANTS
Proceedings of the First International Biomaterials Symposium
Edited by Samuel F. Hulbert and Frank A. Young

A compilation of papers presented at the first Annual Biomaterials Symposium held at Clemson University. The purpose of the symposium was to stimulate interest in the area of 'Bioceramics' by acquainting materials engineers with materials problems that exist in surgery and by reporting scientific work which has demonstrated the feasibility of employing ceramics as materials of construction for surgical implants.

S.F. Hulbert



Summary

- The Precursors
- 1970s : The Pioneers
- 1980 – 2004: The Development
    - Alumina
    - Zirconia
    - ZTA – ATZ composites
- Bioceramics in Hip Joint Replacements Today

The CBS® dental implant (1965)

United States Patent [19]
Sandhaus

[11] **Patent Number: 4,466,796**
[45] **Date of Patent: Aug. 21, 1984**

[54] **DENTAL IMPLANT FOR USE AS A PILLAR IN A MOUTH**

[75] Inventor: **Sami Sandhaus**, Lausanne, Switzerland

[73] Assignee: **CBS Biotechnic SA**, Switzerland

[21] Appl. No.: **312,824**

[22] Filed: **Oct. 19, 1981**

[30] **Foreign Application Priority Data**

Oct. 20, 1980 [CH] Switzerland 7810/80

[51] **Int. Cl.**³ **A61C 8/00**
[52] **U.S. Cl.** **433/173**
[58] **Field of Search** 433/174, 175, 173

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,579,830	5/1971	Morel	433/176
3,672,058	6/1972	Nikoghossian	433/176
4,060,896	12/1977	Wahnish	433/174
4,079,515	3/1978	Friedman	433/173
4,229,169	10/1980	Smith et al.	433/174

FOREIGN PATENT DOCUMENTS

2308348	4/1975	France	433/174
2,063,680	11/1979	United Kingdom	433/174

OTHER PUBLICATIONS

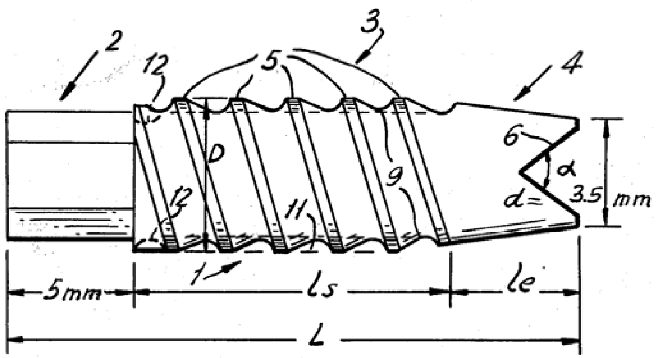
Kawalara et al., of Ser. No. 89,781 filed Sep. 7, 1972, published in vol. 81, 1974, p. 434.

Primary Examiner—Robert Peshock
Attorney, Agent, or Firm—Ostrolenk, Faber, Gerb & Soffen

[57] **ABSTRACT**

The dental implant comprises a head, preferably having a polygonal section like a hexagonal one; a generally central portion provided with a specially shaped thread; and a rear portion which is tapered and provided with a slot over the diameter of the ending surface. The implant is made from bioceramics and adapted to be screwed in a hole previously drilled into the patient's maxillary bone.

6 Claims, 4 Drawing Figures



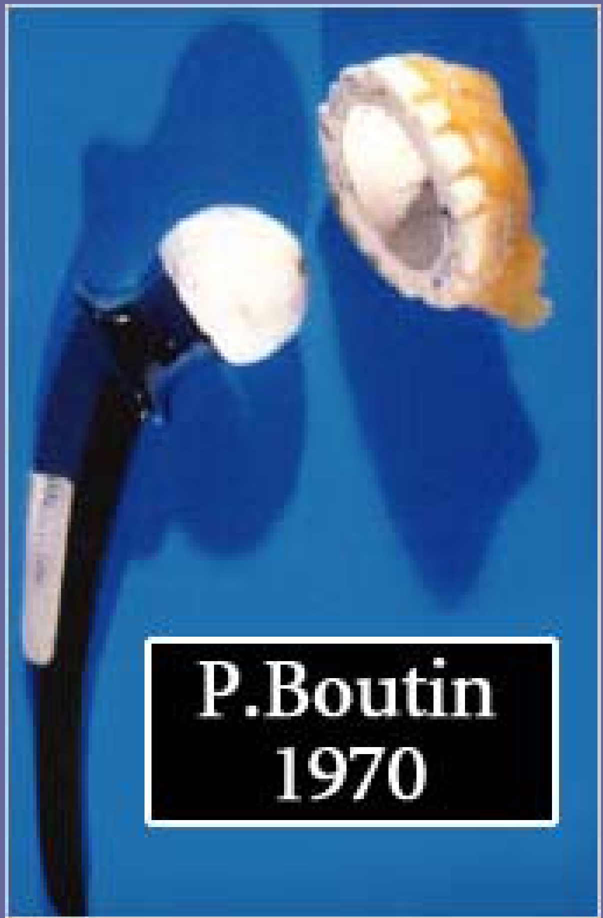
Dr. Sami Sandhaus

The First Ceramic-Ceramic THR bearing (1970)

Pierre Boutin/Daniel Blanquaert

The Ceramic-ceramic THR bearing (1970)

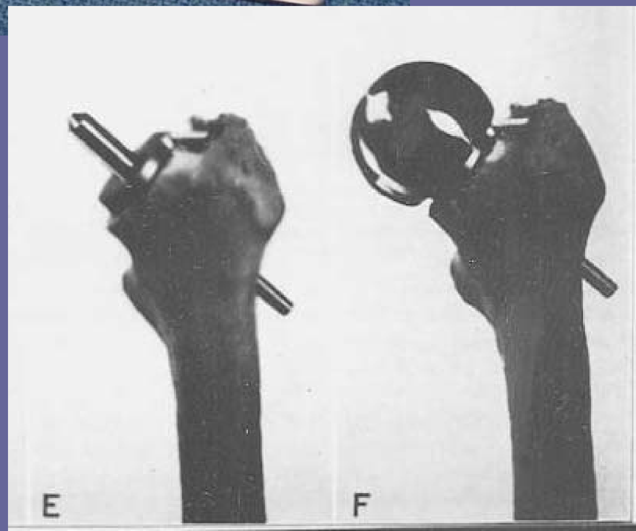
Pierre Boutin/Daniel Blanquaert



- Cemented Stem & Cup

Charnley, 1960. The «Low Friction Arthroplasty»

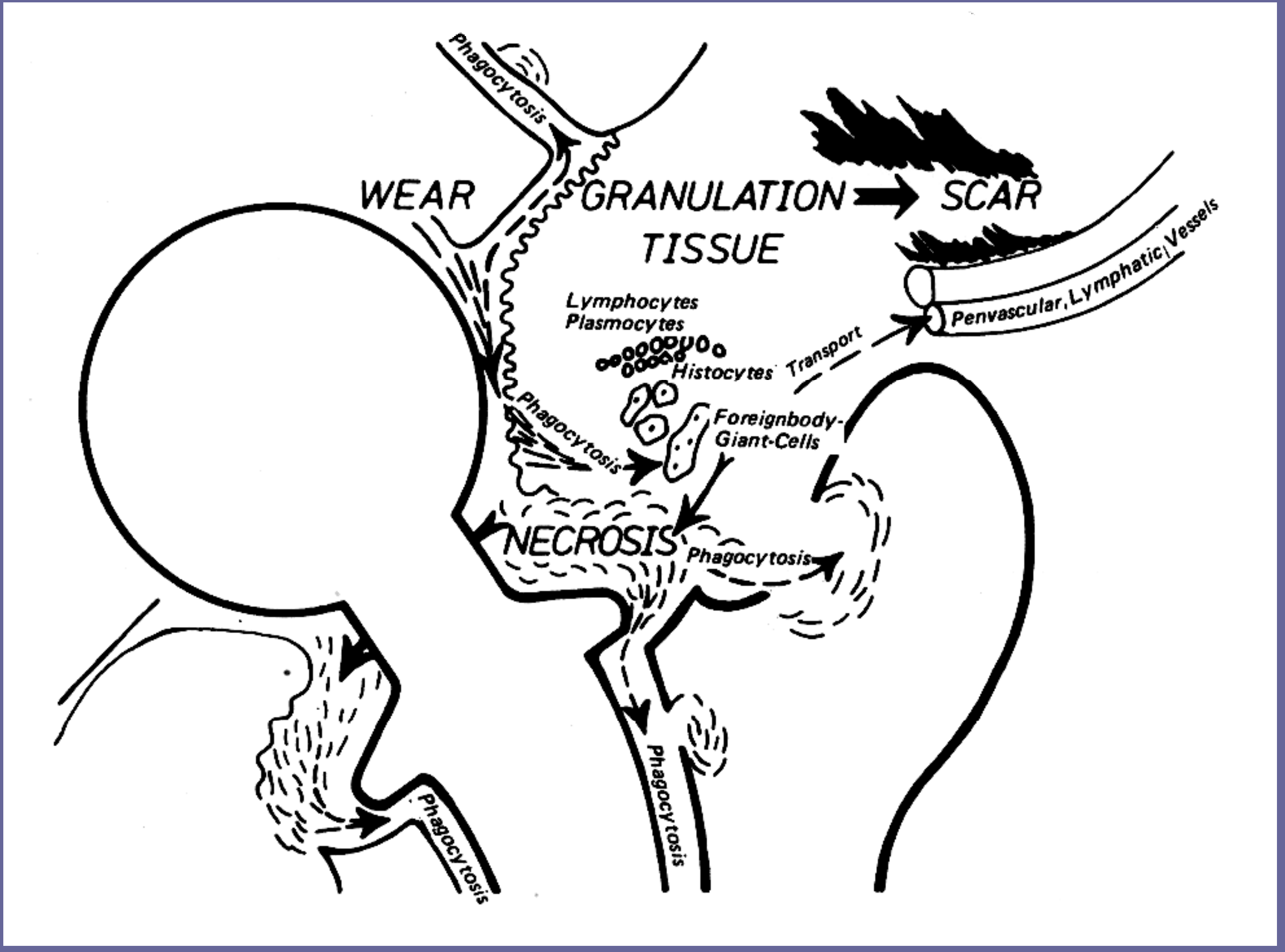
1970's THRs



Loosening & Osteolisys

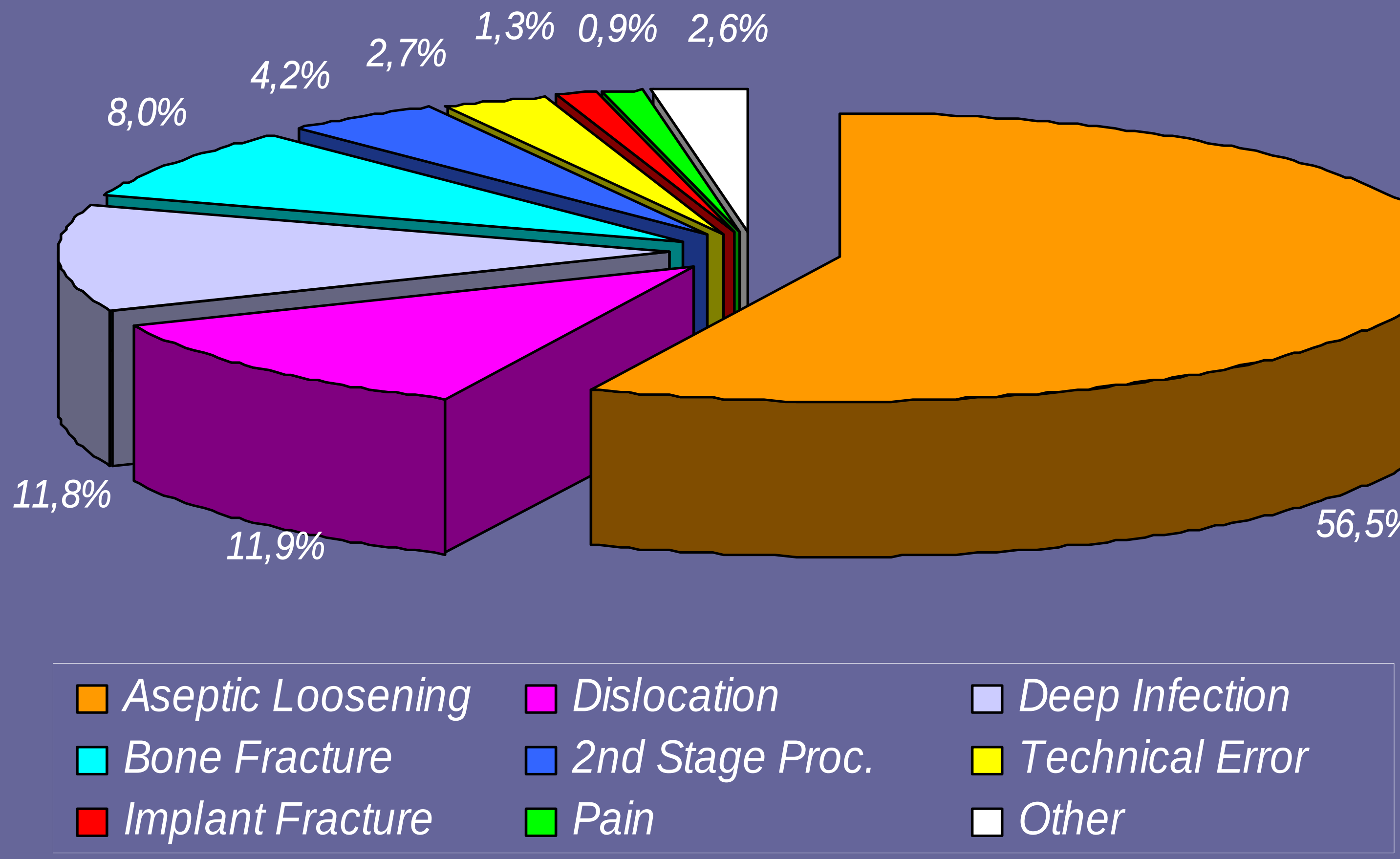
Reactions to THR Wear Debris

Willert & Semlitsch, 1977



THR Reoperation by Diagnosis

Swedish Hip Arthroplasty Register 2010
(41.119 Surgeries, 1979-2007)



Why Alumina?

Behavior of Materials for Hip Replacement Bearings

- Bulk Biological Safety
- Wear Debris Biological Safety
- Mechanical Strength
- Low Wear of the Selected Couple
- Low Friction of the Selected Couple
- Stiffness
- Corrosion Resistance
- Long Term Stability

→ α-Al_2O_3, α- Alumina, Corundum

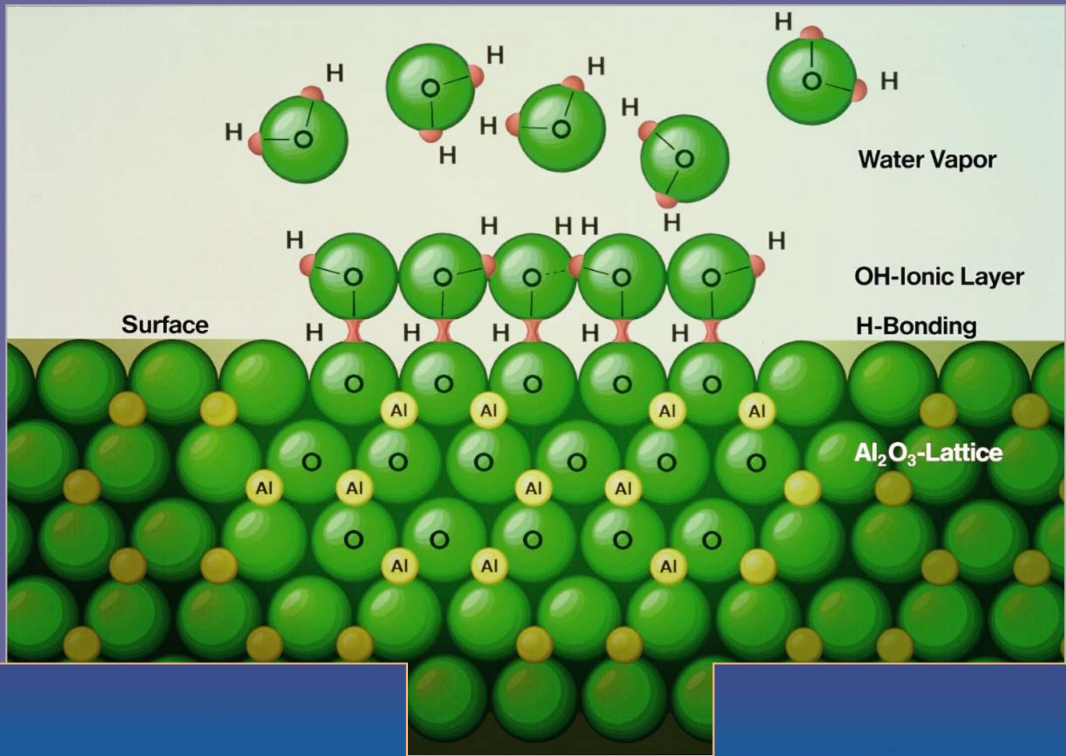
Alumina: *In-vitro Assays*

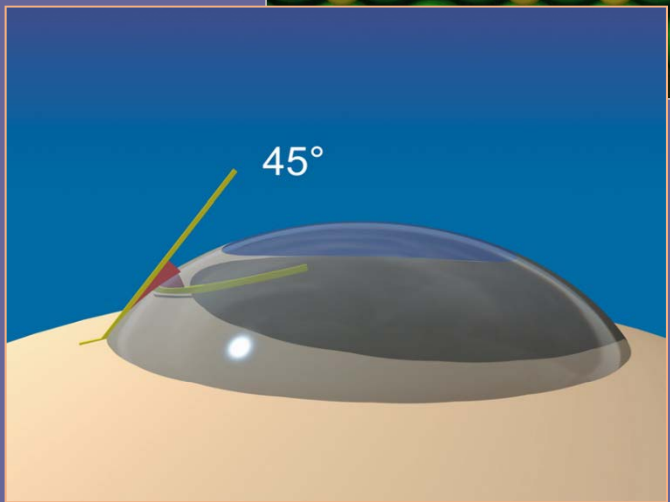
Reference	*Physical form*	*Cell Type*
Harms 1979	powders	macrophages, limphocytes
Pizzoferrato 1982	ceramics	HeLa, 3T3
Bukat 1990	ceramics	3T3
Greco 1993	powders	Human Limph.
Ito 1993	wear debris	L929
Li 1993	powders and ceramics	Human Oral Fibroblasts
Dion 1994	powders	HUVEC, 3T3
Harmand 1995	powders	Fibroblasts
Takami 1997	extracts	Fibroblasts
Catelas 1998	powders	Macrophages
Mebouta 2000	powders	Human Monocytes
Torricelli 2001	powders	Osteoblasts
Lohman 2002	powders	Osteoblasts

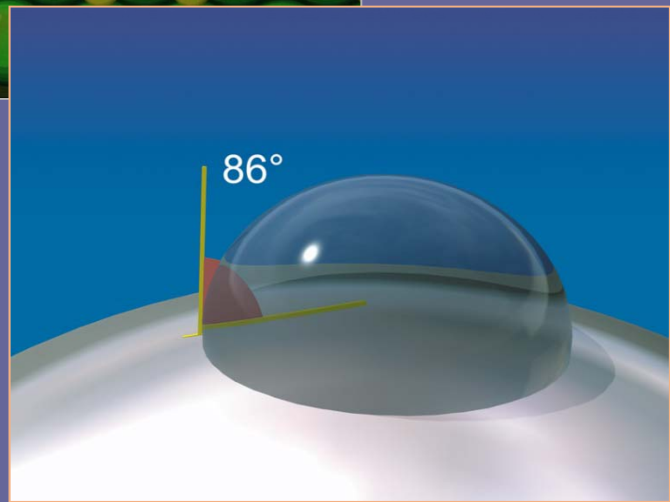
Alumina: *In-vivo Assays*

Reference	*Physical form*	*Animal model*	*Implant site*
Helmer 1969	Pellets	Monkey	Femur
Hulbert 1972	Porous and non porous disks and tubes	Rabbit	Paraspinal muscle
Griss 1973	Slurry	Swiss mice	Subcutis, knee
Harms 1979	Powders	Mice	Intraperitoneal, intramuscular
Garvie 1984	Bars	Rabbit	Paraspinal muscle
Wagner 1986	Pins	Rat	Femur
Christel 1988	Pins	Rat	Paraspinal muscle
Christel 1989	Pins	Rabbit	Femur
Maccauro 1992	Powders	Mice	Intraperitoneal
Specchia 1995	Pins	Rabbit	Femur
Warashina 2003	Powders	Rat	Calvaria

Alumina: Surface Wettability

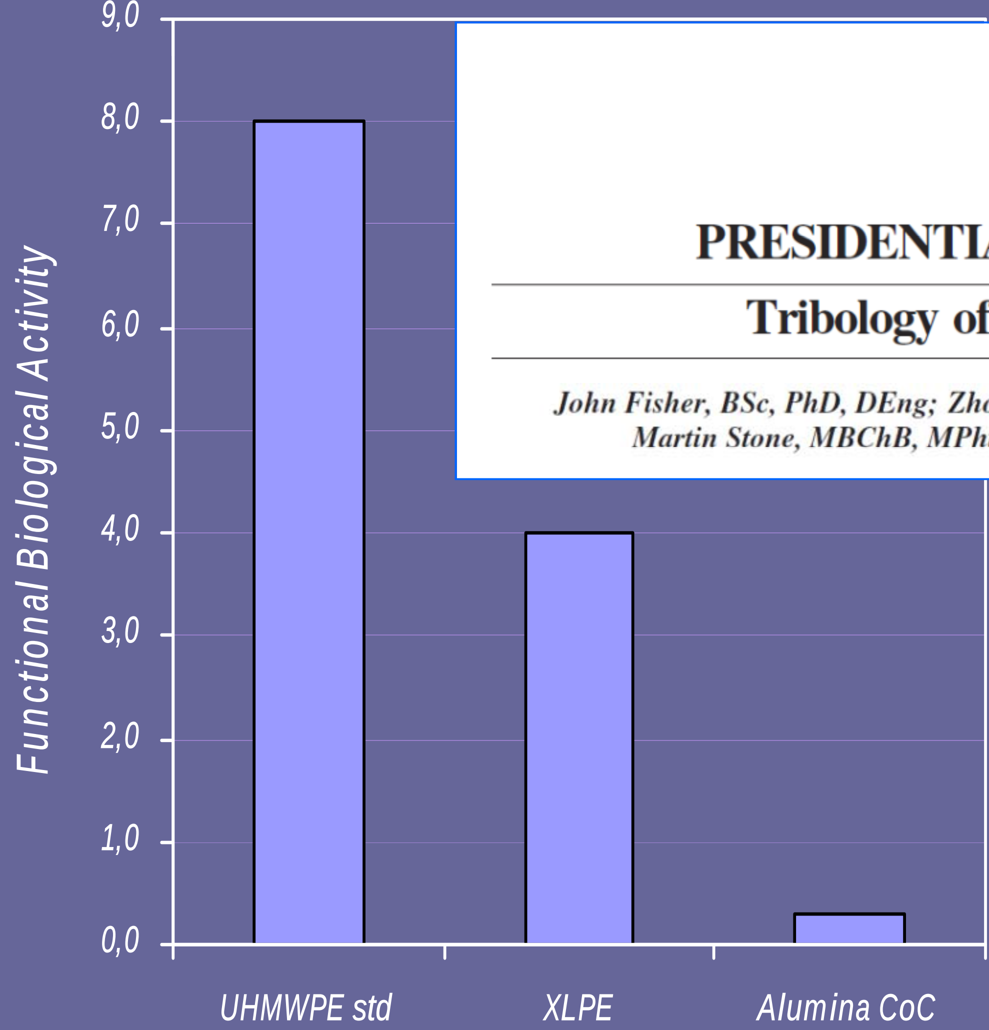






Wear in THR Bearings

Ceramic Wear Debris:
Functional Biological Safety



CLINICAL ORTHOPAEDICS AND RELATED RESEARCH
Number 453, pp. 25–34

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PRESIDENTIAL GUEST LECTURE

Tribology of Alternative Bearings

John Fisher, BSc, PhD, DEng; Zhongmin Jin, BSc, PhD; Joanne Tipper, BSc, PhD; Martin Stone, MBChB, MPhil, FRCSEd; and Eileen Ingham, BSc, PhD

FBS = Biological Activity * Wear

The German R&D Program (1972)

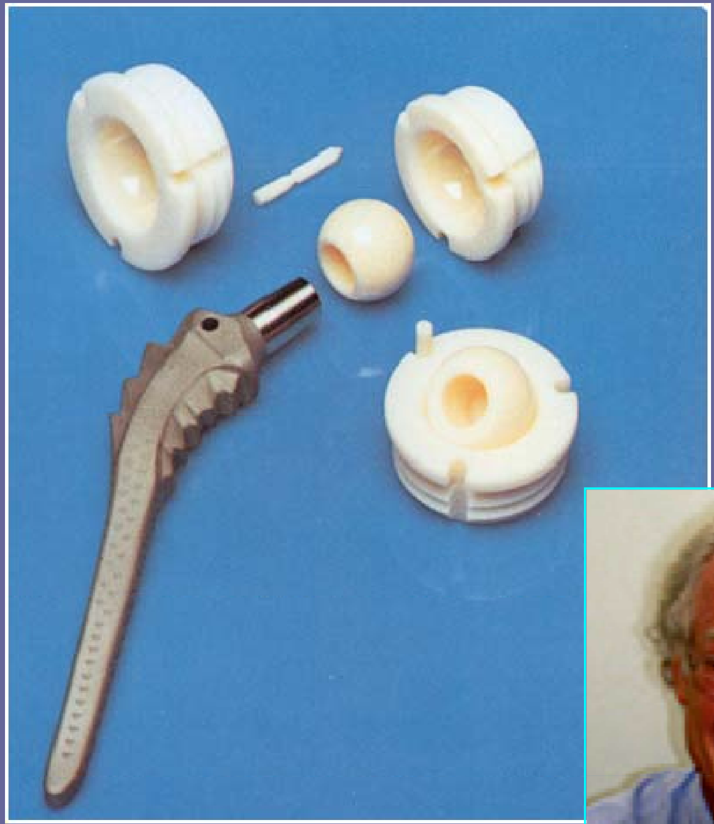
Herlhad Dörre

Günther Heimke

The German THRs (1974)

- Uncemented Stem & Cup
- Head-stem modular taper connection

H. Mittelmeier

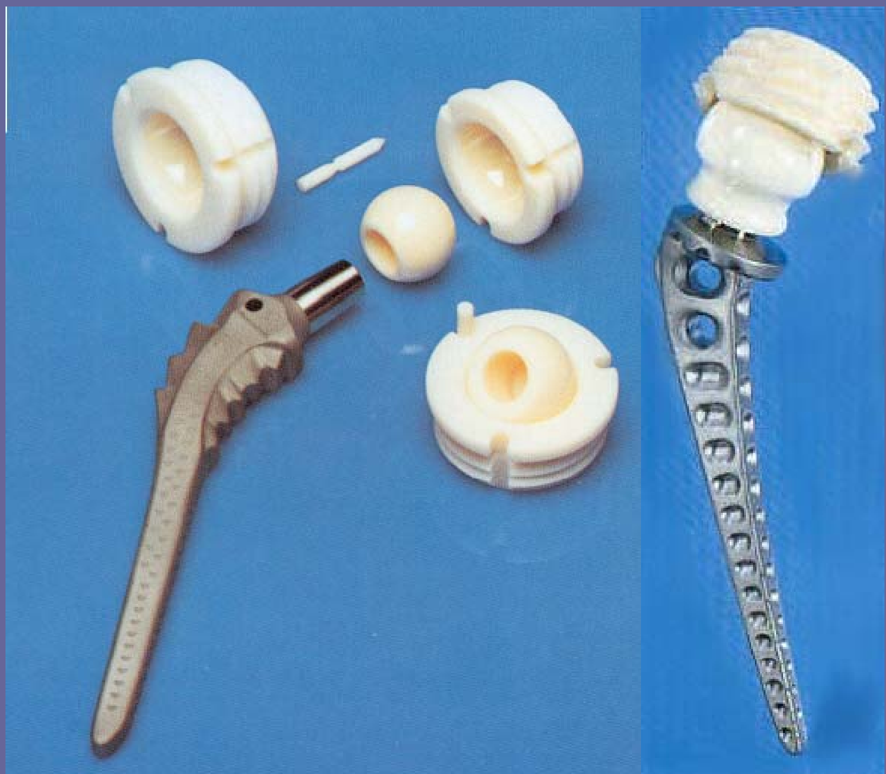


K. Griss

The Taper Connection (1974)

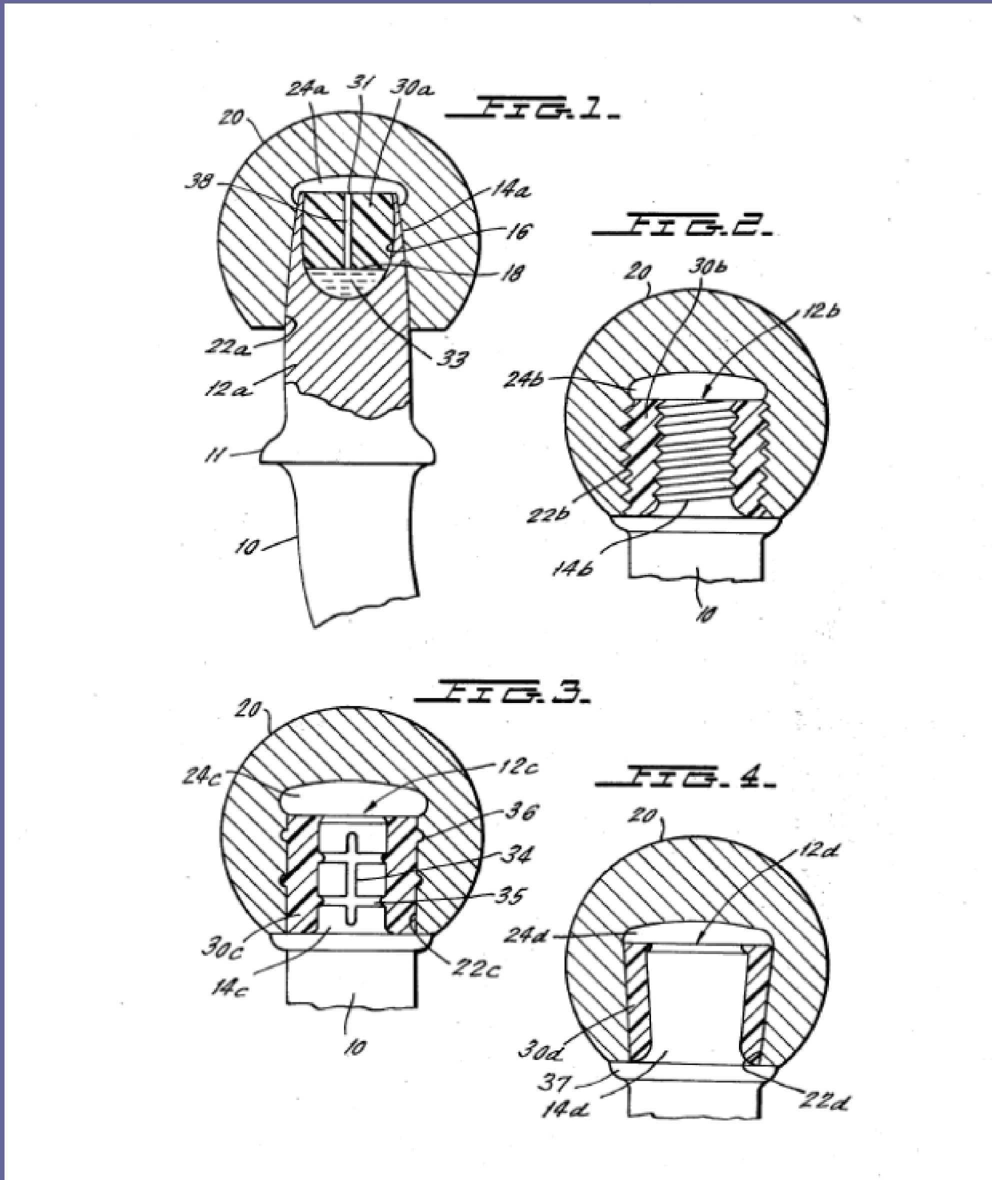
12/14, 1:10 taper,

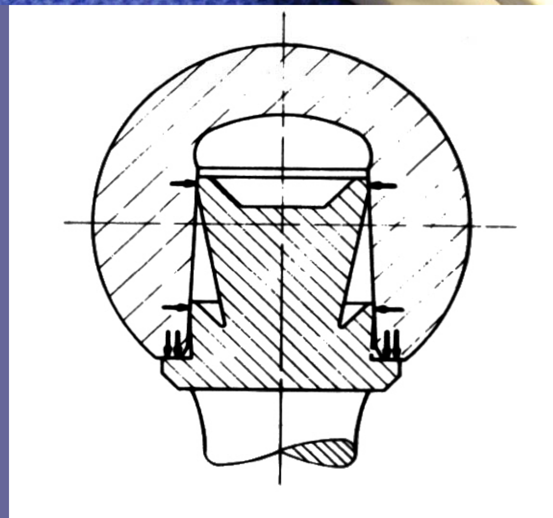
angle: 5°43'30"



- Easy connection
- Stable
- Absence of adhesives or solders

THR: Metal-Ceramic connections (1970s)

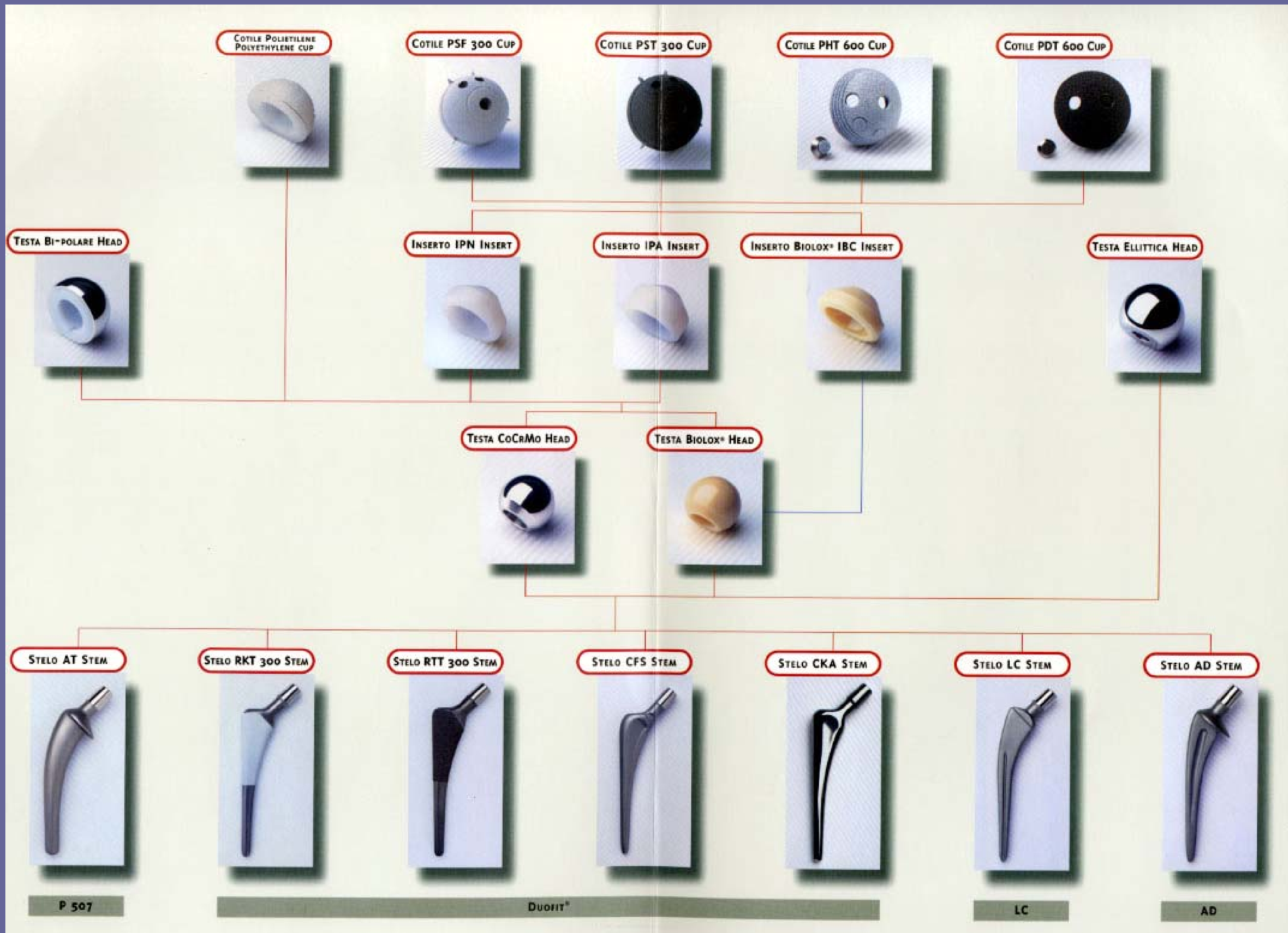




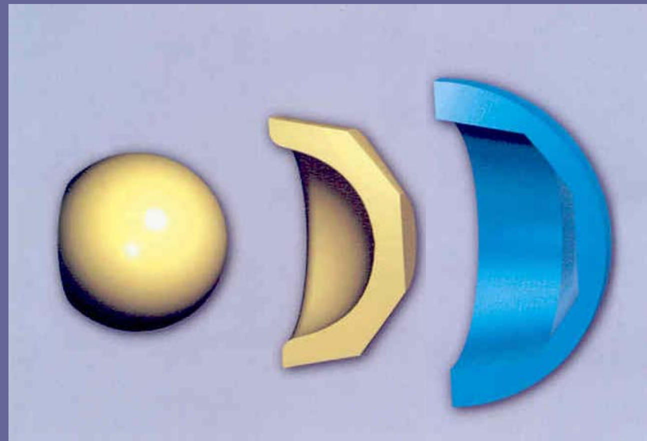
The Ceramic-ceramic THR bearing (1970)
Pierre Boutin/Daniel Blanquaert

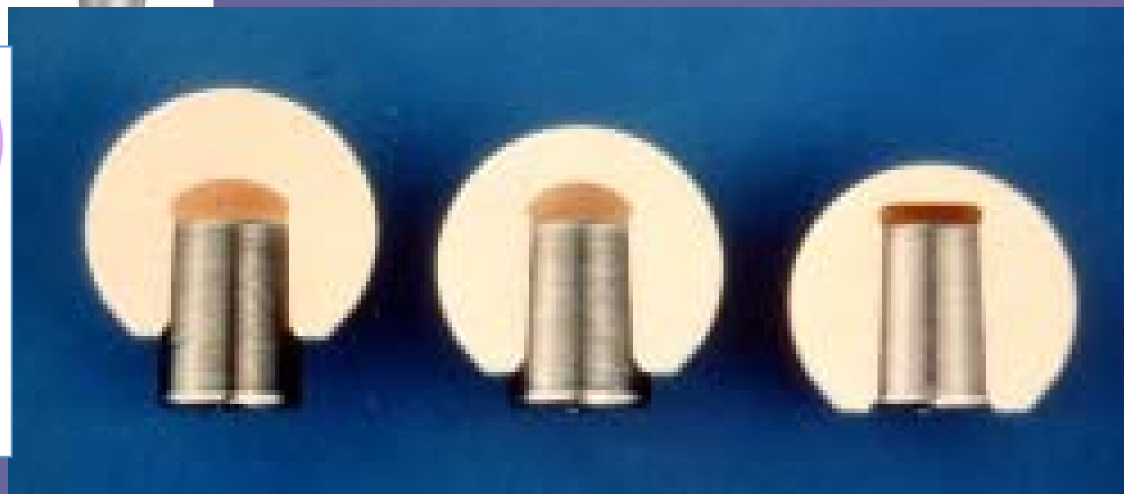
- Cemented Stem & Cup
- Head-stem connected by epoxy glue
- Head-stem screw connection

Taper Connection = Modularity



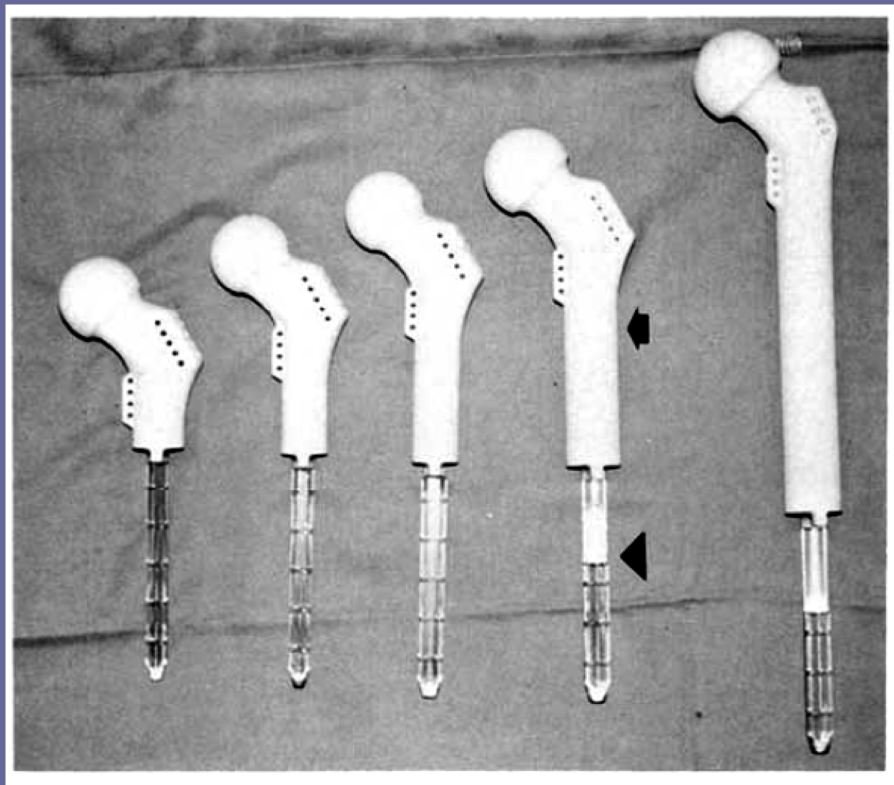
Taper Connection = Modularity

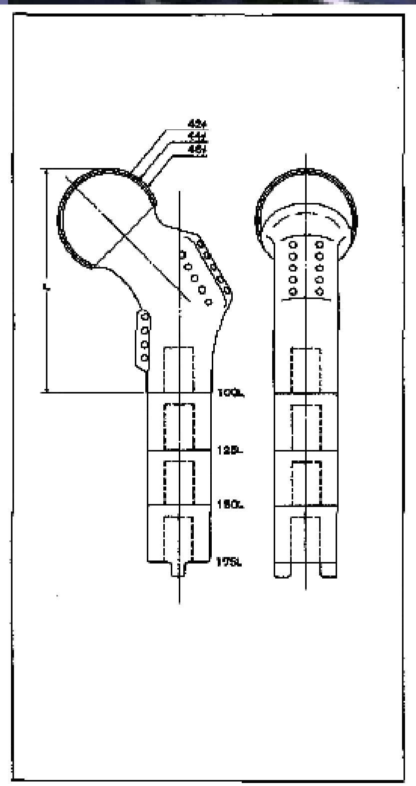




Alumina Hip & Knee Replacements

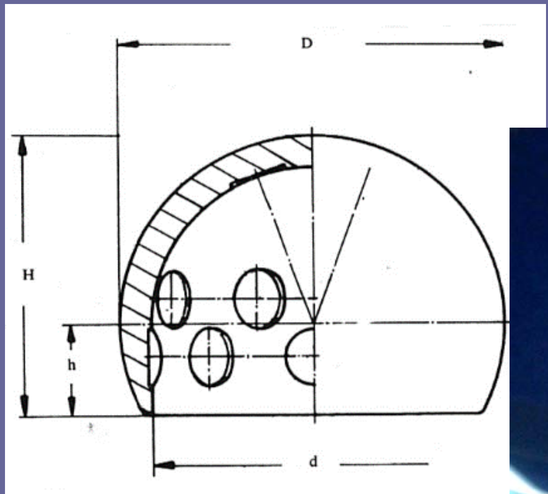
Sapphire Bioceram® (Hayashi, 1975)





Alumina Hip Replacements

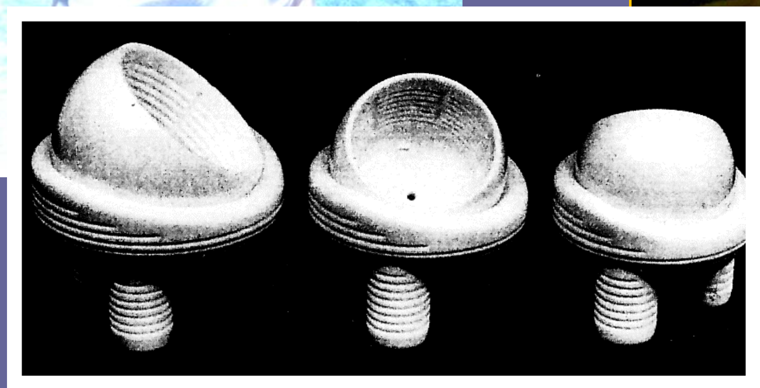
Stärk N., Rosenthal Technik Bioceramics



D	d	H	h
38	33	27	8
42	36	29	8
45	39,5	31,5	8,5
50	44	33,5	8,5

misure in mm

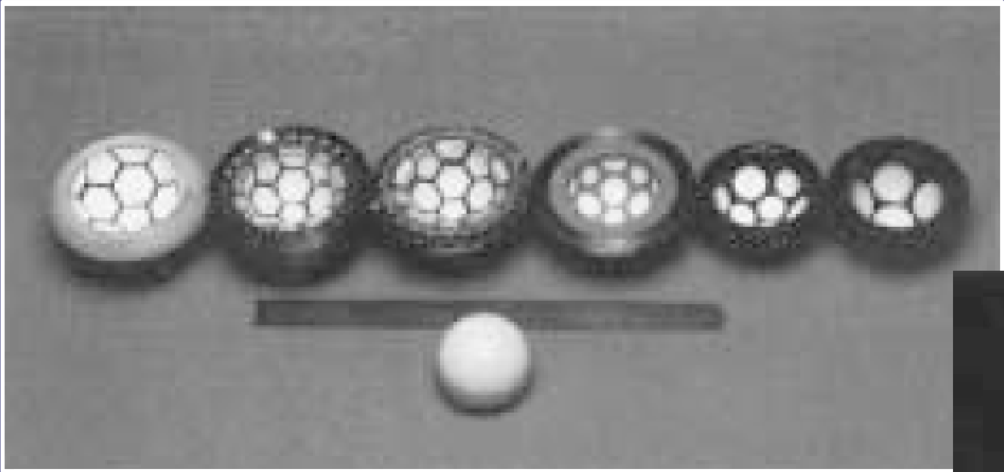
(Wagner, 1978)



(Saltzer, et al., 1978)

Alumina Hip Replacements

McTighe T: The “Soccer Ball” Socket



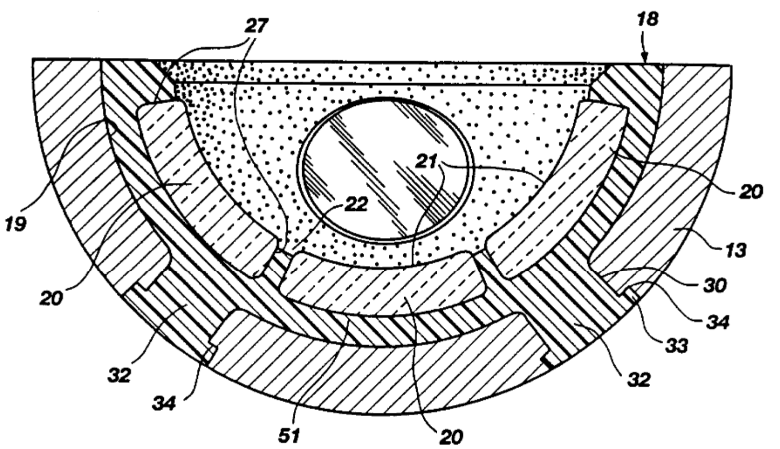
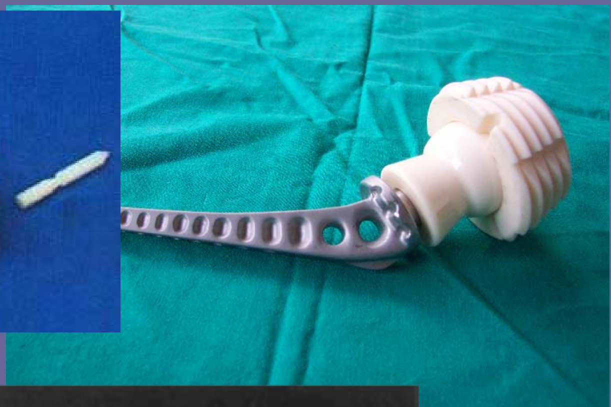
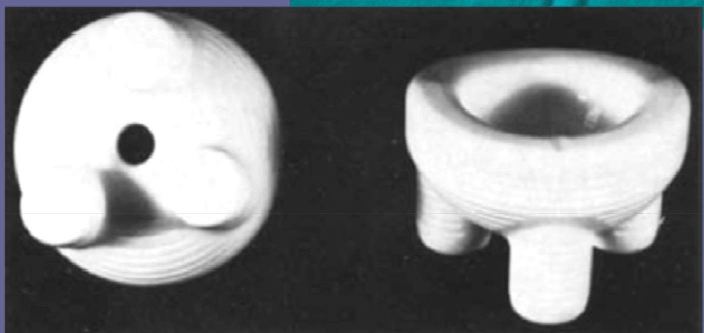


Fig. 3

Early Failures, EarlyLessons





- Head-stem dissociation due to poor fixation (Boutin)
- Socket mobilization due to lack of osteointegration (Mittemeier, Griss, Chiari)

BUT:

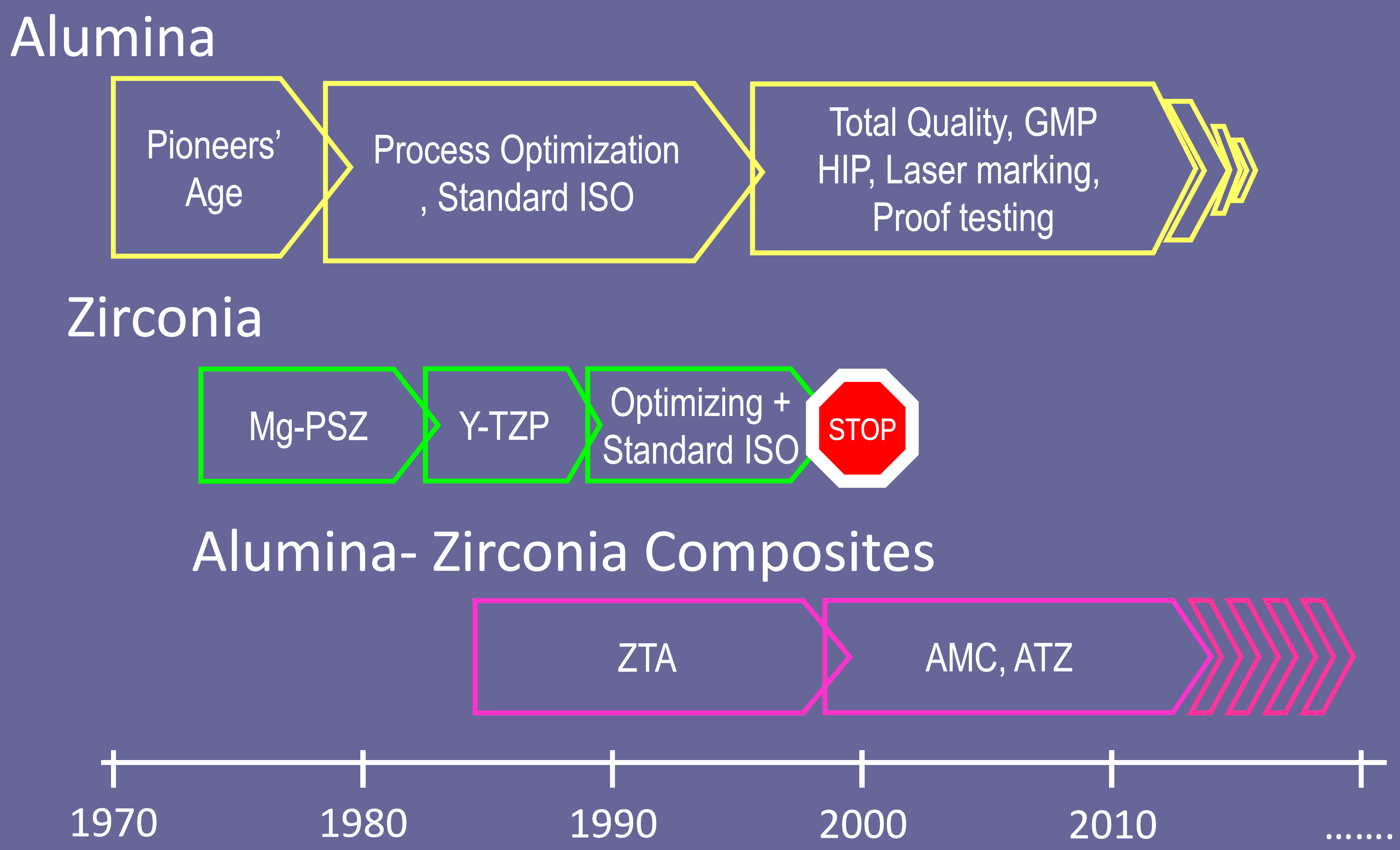
- Low wear
- No osteolysys
- Lack of systemic reactions

Summary

- The Precursors
- 1970s : The Pioneers
- 1980 – 2004: The Development
  - Alumina
  - Zirconia
  - ZTA – ATZ composites
- Bioceramics in Hip Joint Replacements Today

Ceramics for Joint Replacement Bearings

Timescale



Development of Ceramic for TJR Bearings: *Objectives*

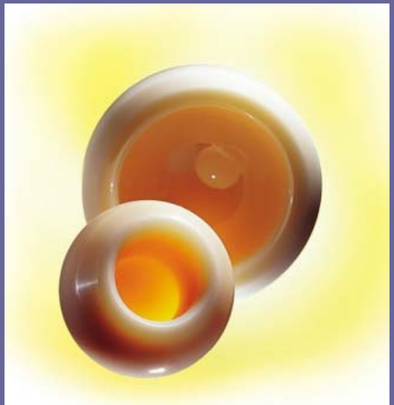
- Increase Strength & Wear Resistance
- Maximize Reliability
- Get Flexibility in Device Design
- Contain Production Costs

Development of Ceramic for TJR Bearings: *Approaches*

Increase Strength by:

- Increase in Density
- Reduction of grain size

Improved Alumina



Development of intrinsically tough ceramic

Zirconia

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- The Precursors
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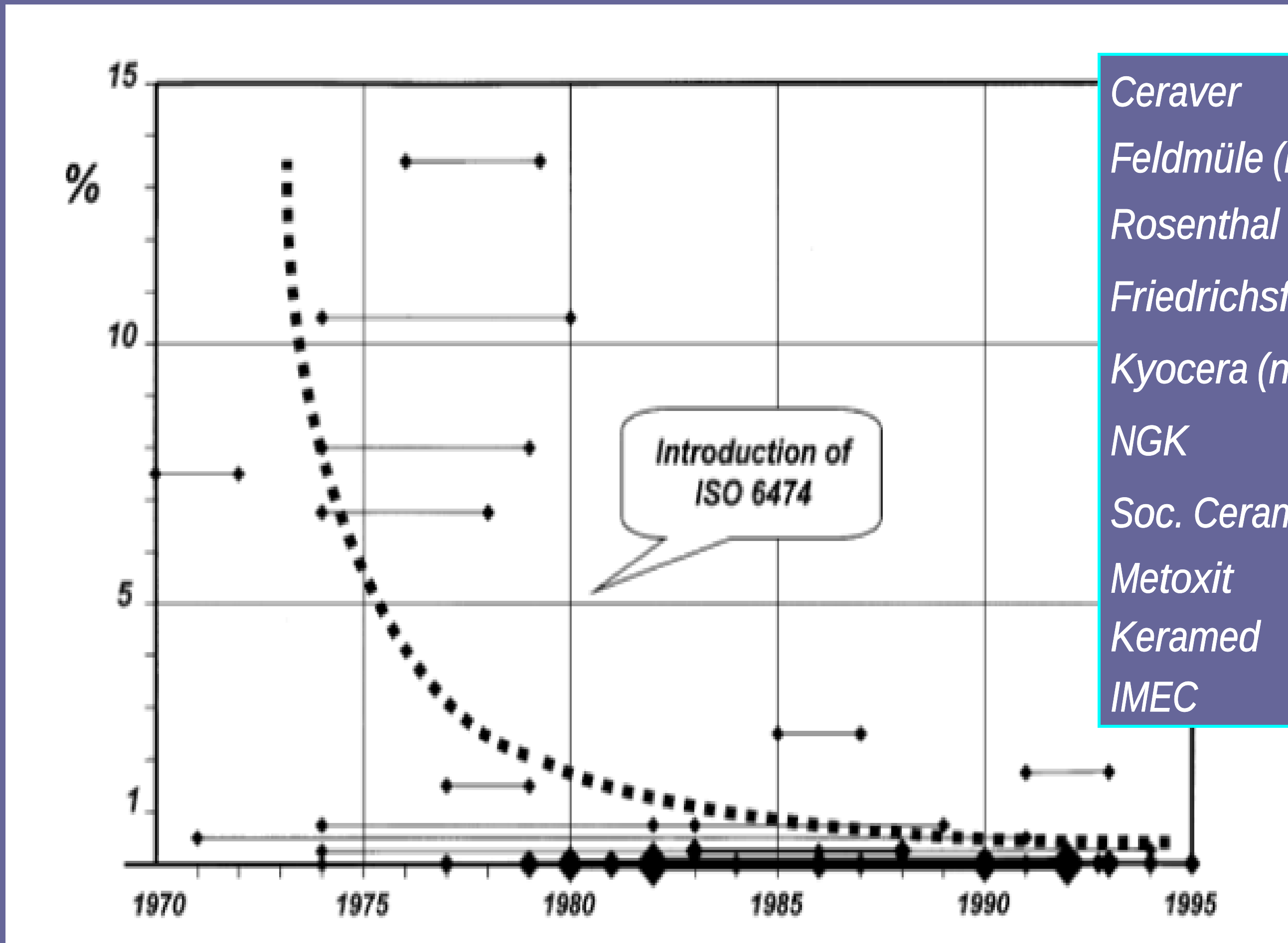
Reliability of Alumina Components:
Ball Heads Rate of Fracture 1970-1995

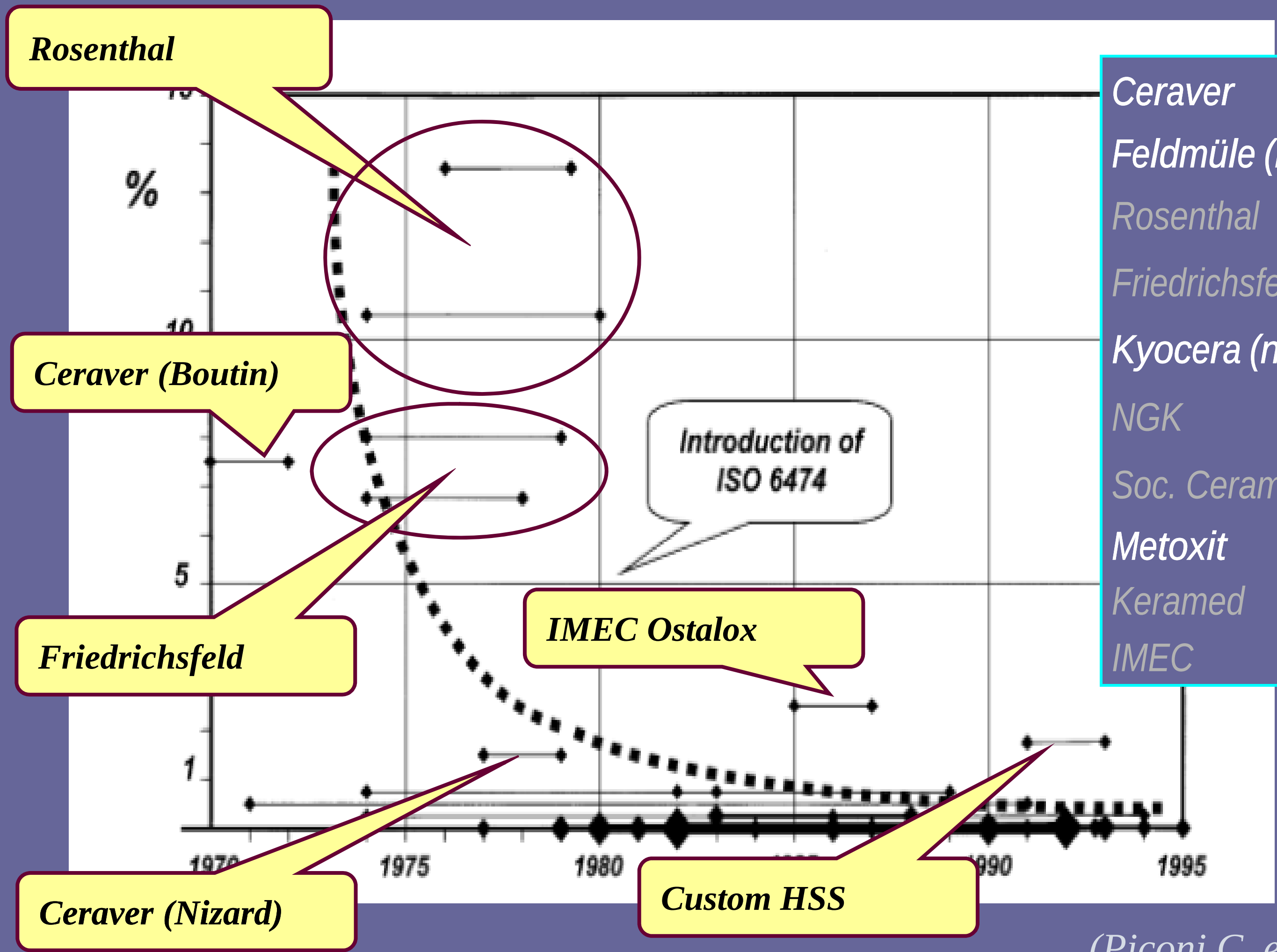


Ceraver	F
Feldmüle (now Ceramtec)	D
Rosenthal	D
Friedrichsfeld	D
Kyocera (now JMM)	J
NGK	J
Soc. Ceramiques Techniques	F
Metoxit	CH
Keramed	D
IMEC	I

(Piconi C, et al. Biomaterials 1999)

Reliability of Alumina Ball Heads:

Rate of Fracture 1970-1995



Ceraver	F
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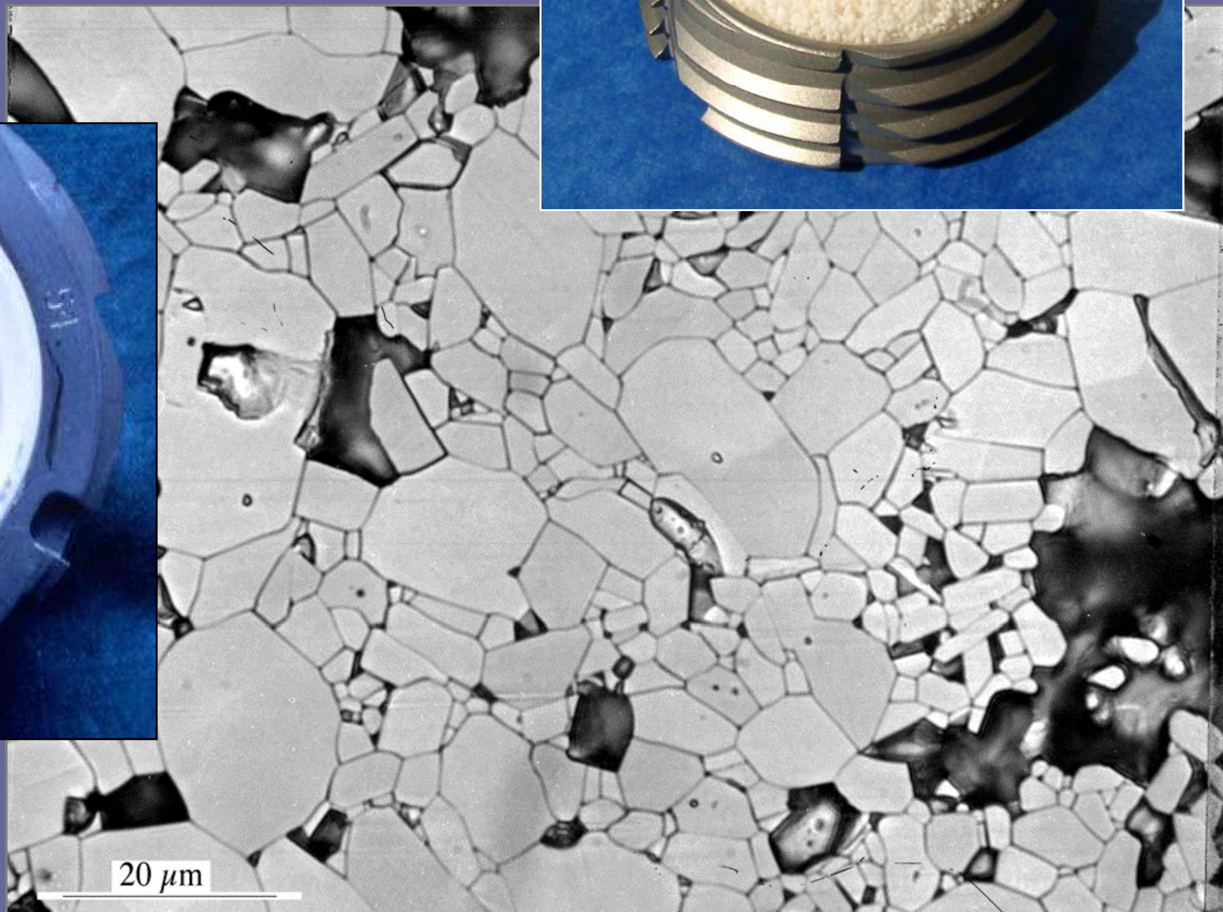
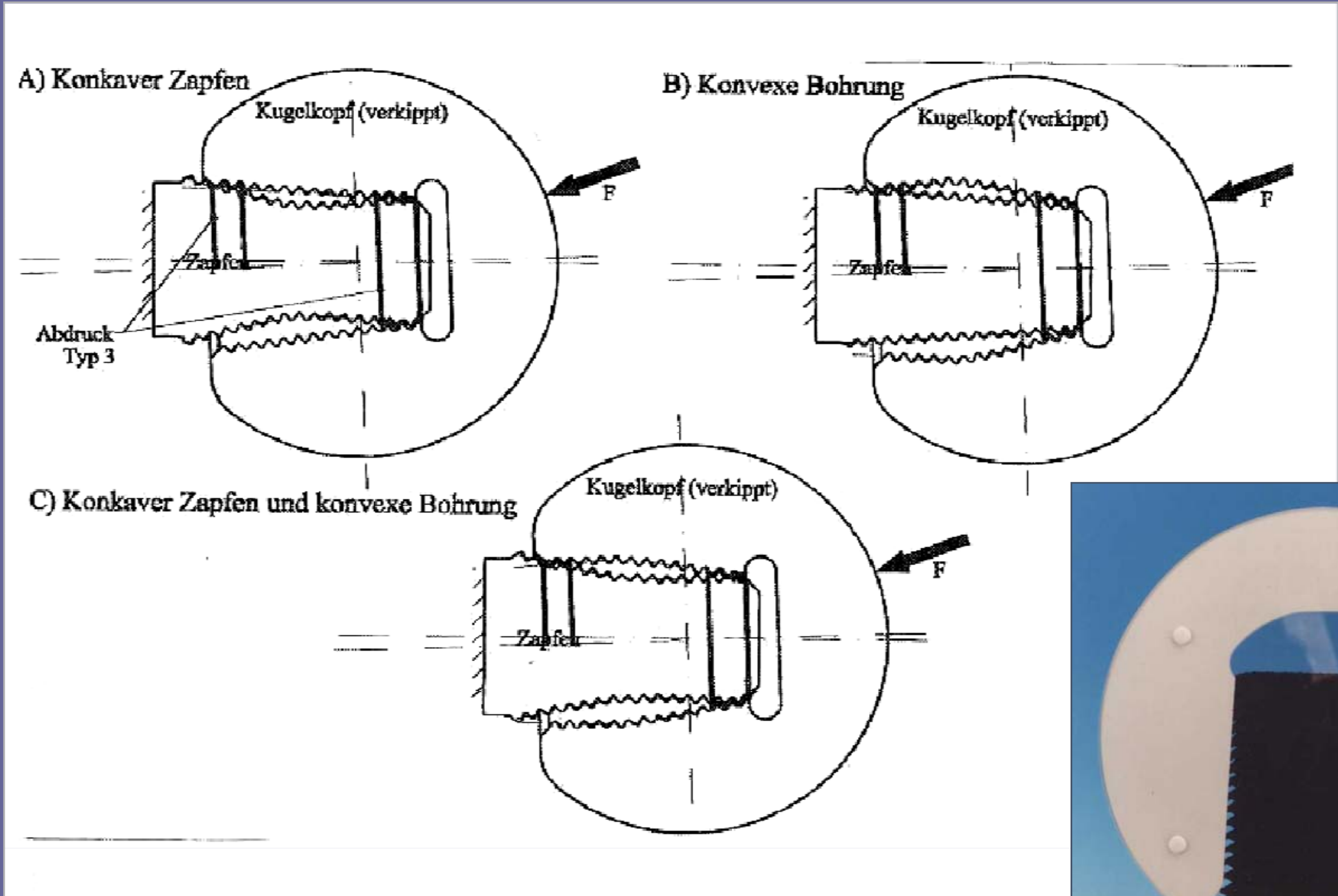
NGK	J
Soc. Ceramiques Techniques	F
Metoxit	CH
Keramed	D
IMEC	I

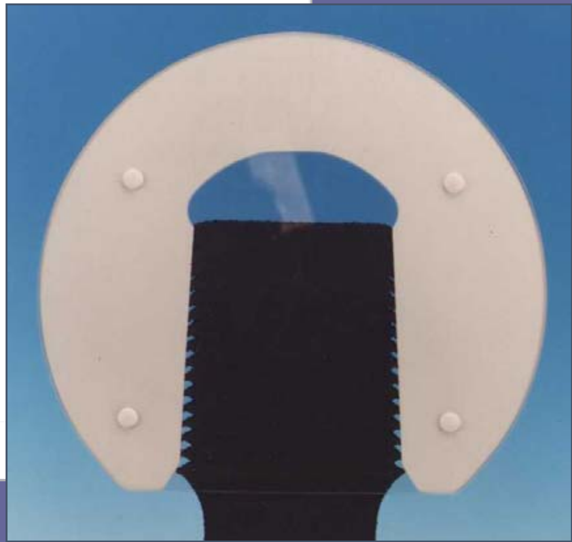
(Piconi C, et al. Biomaterials 1999)

IMEC Ostalox™



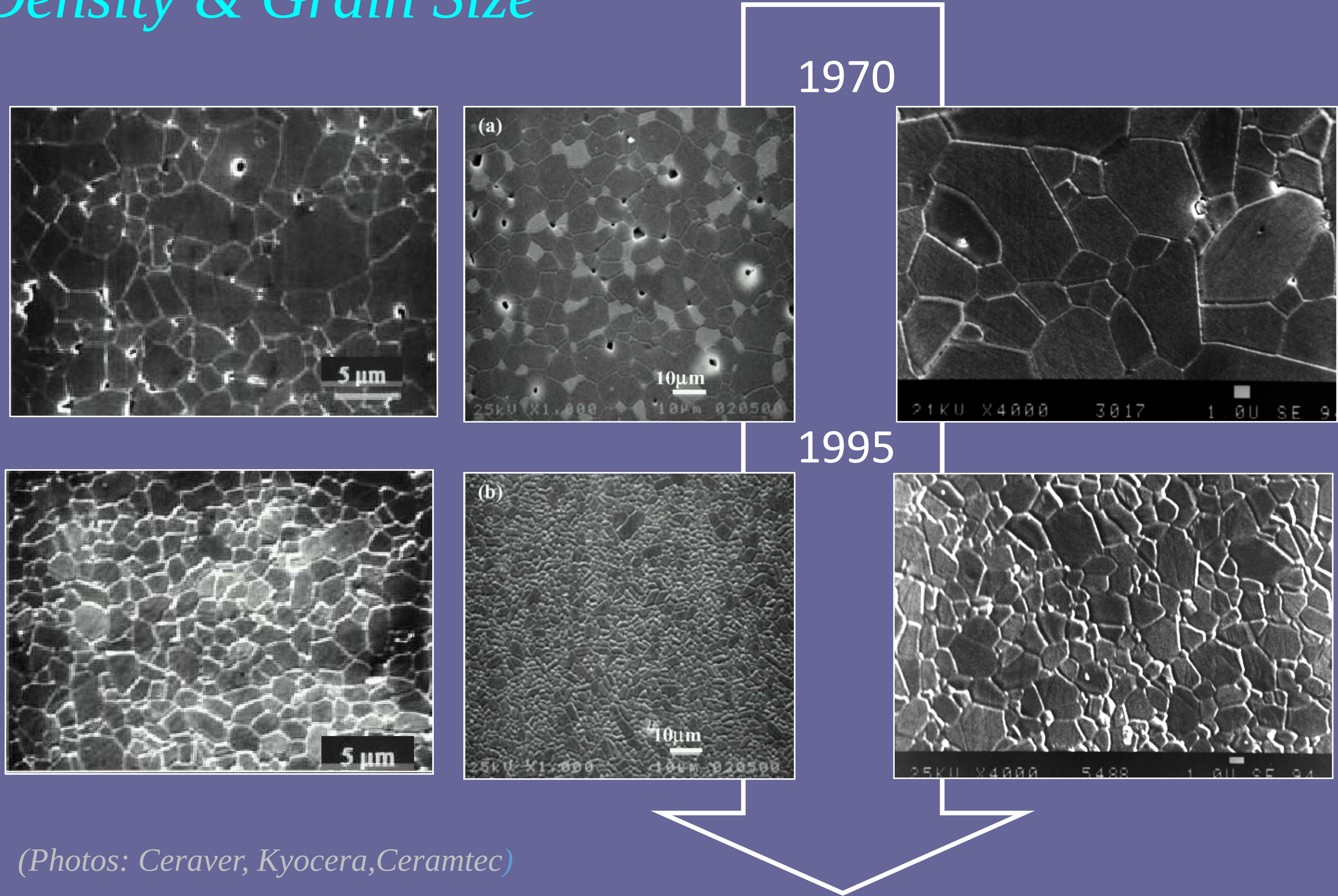
Custom-made tapers:
Machining Tolerances





Material Development

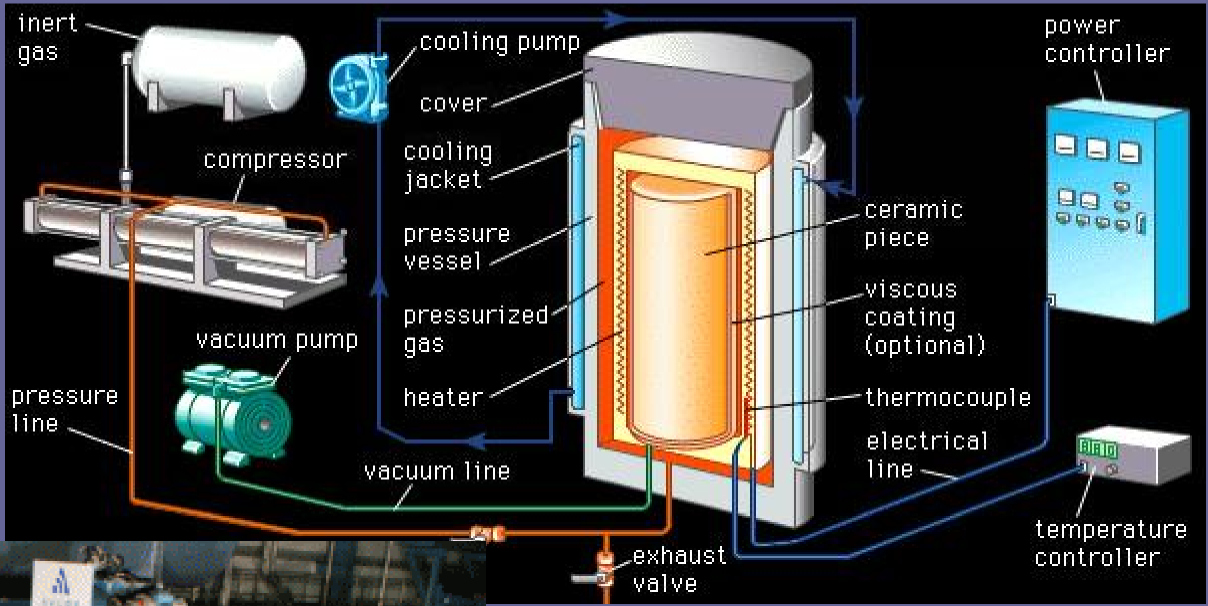
Density & Grain Size



(Photos: Ceraver, Kyocera,Ceramtec)

Material Development

Hot Isostatic Pressing (HIP)

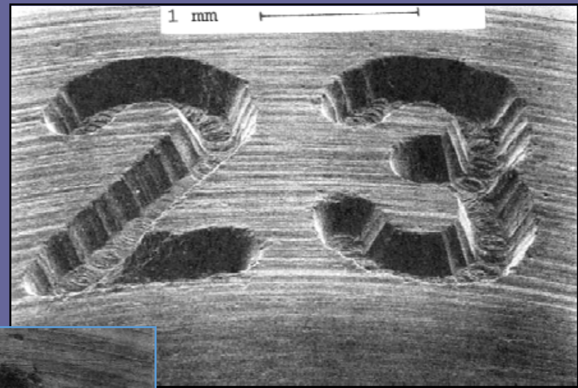


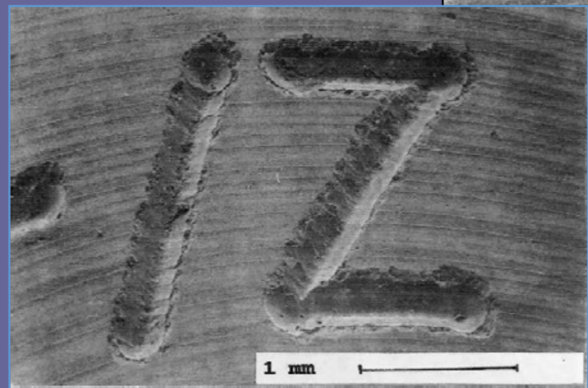
Improvements in BIOLOX Alumina 1974-1995

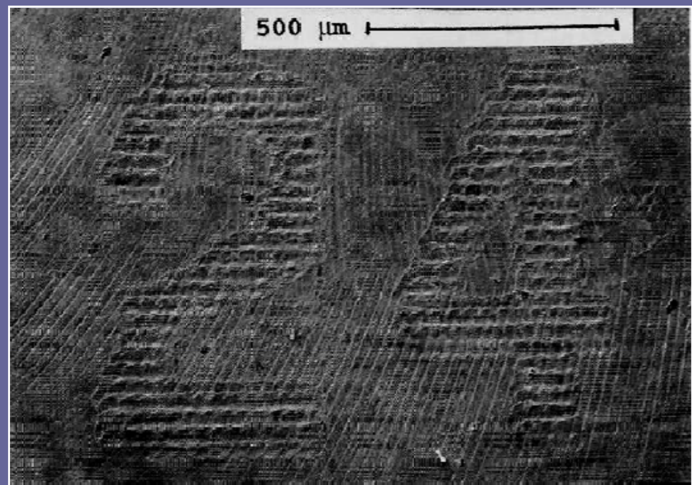
	Unit	BIOLOX® (since 1974)	BIOLOX® *forte* (since 1995)
Content α - Al_2O_3	Vol-%	99,7	> 99,8
Density	g/cm^3	3,95	3,97
Grain size	µm	4	1,750
4-Pt. Bending strength	MPa	500	631
Young‘s modulus	GPa	410	407
Fracture toughness K_{IC}	MPa √m	3,0	3,2

Process development

Laser Marking

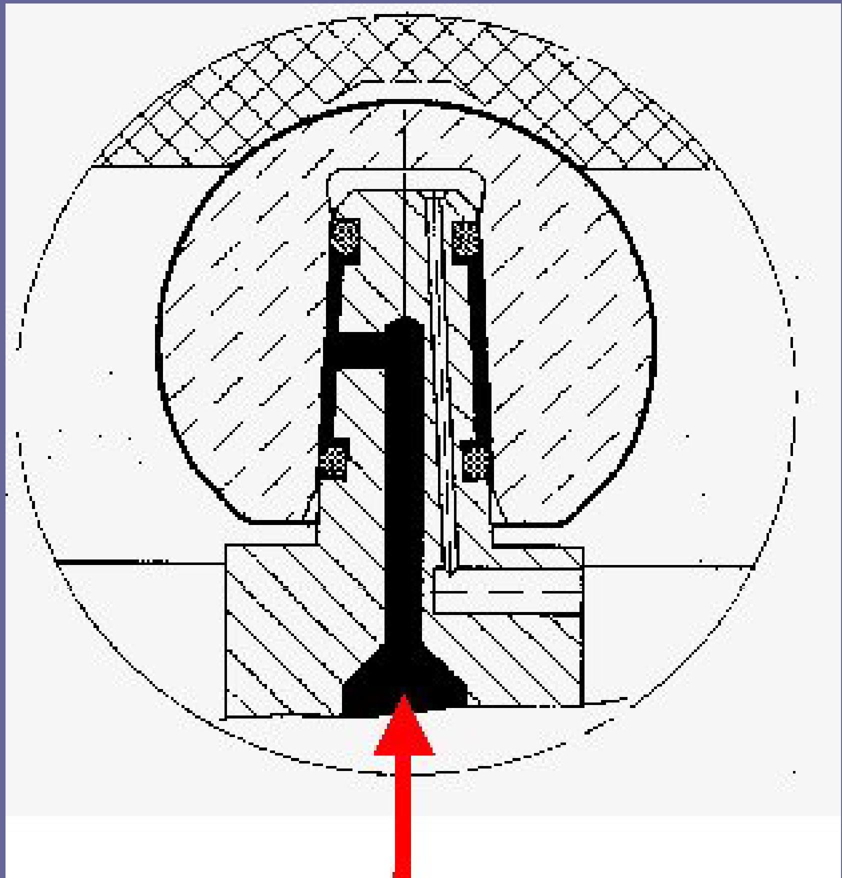


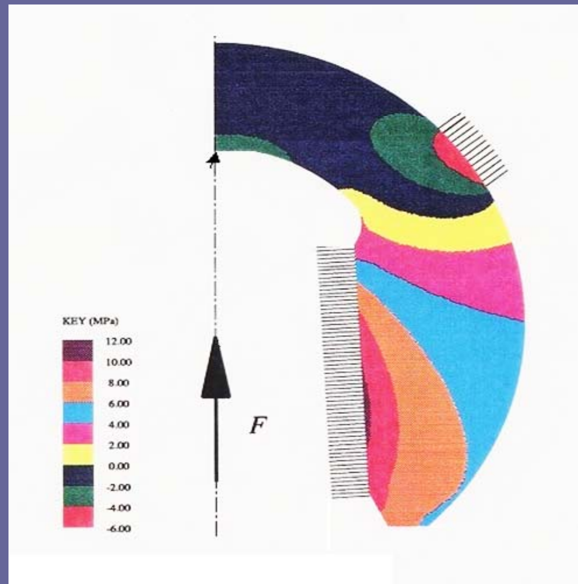




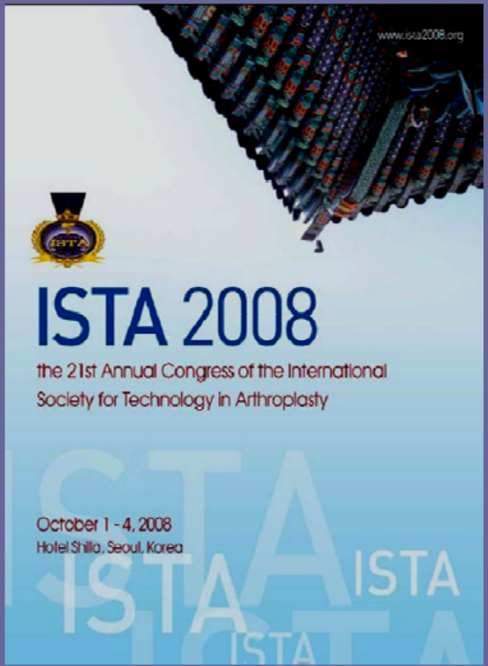
Process development

Proof testing





Alumina:
Fractures 2000-2008



Publ. Year	*Author*	*F.U. (year)*	*# Case*	*#Fractures*
2000	Ueno	>10	27738	9
2000	Boeler,et al.	6	243	0
2000	Bizot,et al.	>5	234	1
2000	Garino	1-3	333	0
2001	Urban, et al.	17-21	64	0
2001	Delaunay, et al.	5-10	133	0
2001	Bizot	<3	96	1
2001	Hammadouche	>18	118	0
2002	D'Antonio	3	345	0
2002	Bierbaum, et al.	4	514	0
2003	Hannouche, et al.	25	5500	8
2005	Capello, et al	4	514	0
2005	Kawanabe, et al.	7-21	215	0
2006	Murphy, et al.	2-8	194	0
2006	Slack, et al	13-15	116	0
2007	Lusty, et al	5-7	301	0
2008	Koo, et al.	3-4	367	5

Device Handling

MDA SN2002(05)
February 2002

MDA MEDICAL DEVICES AGENCY

SAFETY NOTICE

Best practice in use of ceramic femoral heads in hip replacement implants

MANUFACTURER/SUPPLIER
Various orthopaedic implant manufacturers and suppliers

PROBLEM
The orthopaedic literature describes, in general, good clinical performance of ceramic femoral heads in hip replacement implants, including reduction of wear rates. However, MDA receives periodic reports of fracture of ceramic femoral heads. Although it is often not possible to identify the reasons for the failure in individual cases, clinical practice can affect the performance of ceramic femoral heads.

For the attention of:

Health Authorities (England)	- Chief Executives
NHS Trusts (England)	- Chief Executives

ACTION
Follow manufactur
ceramic femoral he

Mix and match o
1. Do not use a ce
a femoral stem
2. Only use ceram
specifically rec
3. Do not use fem
interface unless
by one manufacturer;

Surgical Techni
4. Do not use exc
a ceramic femo
hammer/mallet
ceramic head d
5. Do not implant
6. Ensure that fem
and dry prior to

Revision
7. Do not implant
revision if the s
designed by the

Sterilization
8. Do not resteriliz

Random Mix & Match

Surgical Technique

Re-use of damaged components

Thermal/Mechanical shock

Mix and match of design/manufacturer
1. Do not use a ceramic femoral head supplied by one manufacturer with a femoral stem supplied by another manufacturer;
2. Only use ceramic femoral heads in combination with stems or cups specifically recommended by the manufacturer;

Surgical Technique
4. Do not use excessive force (particularly impact) during attachment of a ceramic femoral head to a stem; do not allow a metal hammer/mallet or other hard item to come into contact with the ceramic head during impaction;
5. Do not implant used, dropped or damaged ceramic femoral heads;
6. Ensure that femoral stem and ceramic femoral head tapers are clean and dry prior to implantation;

Alumina in THR
Summary

- Pros
  - Optimum Biological Safety
  - Good Strenth
  - Low Wear (CoC, CoP)
- Cons
  - Low Toughness
  - Limits in Design Flexibility

Summary

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  - Zirconia
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- Bioceramics in Hip Joint Replacements Today

Zirconia : First studies

1975: Cranin NA, Schnitman PA, Rabkin R, Dennison.
Alumina and Zirconia coated Vitallium Oral Endosteal Implants in Beagles

1975: Kenner GH, Pasco WD, Frakes JT, Brown SD. Mechanical properties of calcia stabilized zirconia following in vivo and in vitro aging

1981: Monticelli G, Santori F, Sandrolini-Cortesi S, Sandrolini-Cortesi M. First considerations of the use of ZrO2 in hip prosthesis stem coating

1984: Garvie RC, Urbani C, Kennedy Dr, McNeuer JC. Biocompatibility of Magnesia-Partially Stabilized Zirconia (Mg-PSZ ceramic)

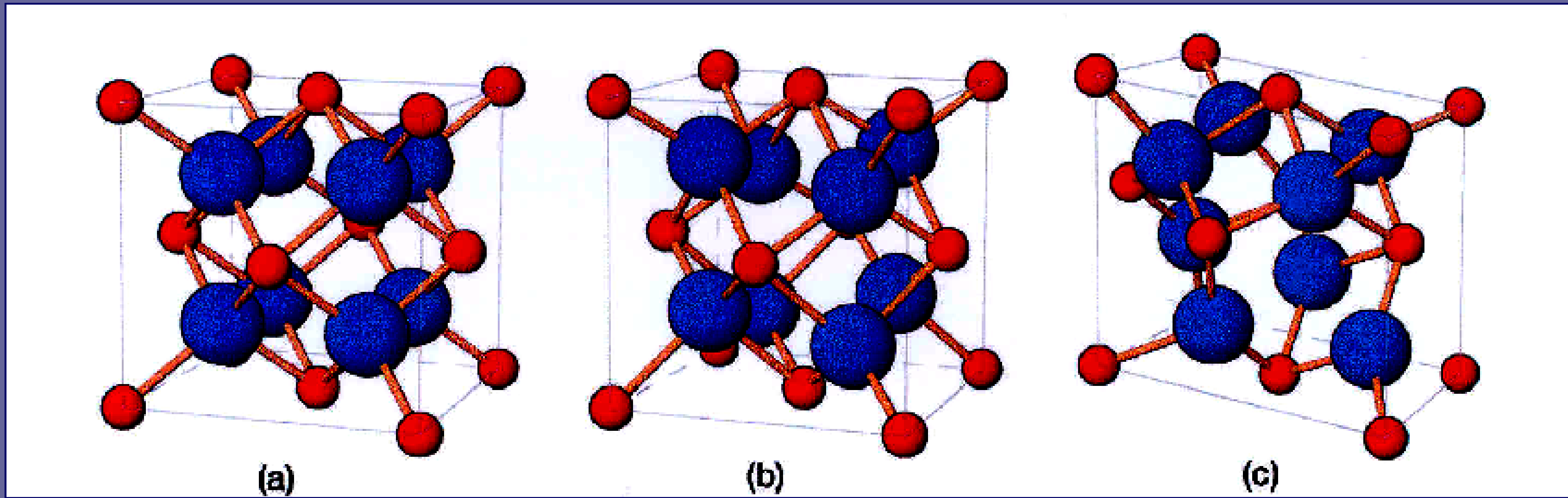
Zirconia: *In-vitro Assays*

Reference	*Physical form*	*Cell Type*
Bukat 1990	ceramics	3T3
Greco 1993	powders	Human Limph.
Ito 1993	wear debris	L929
Li 1993	powders and ceramics	Human Oral Fibroblasts
Dion 1994	powders	HUVEC, 3T3
Harmand 1995	powders	Fibroblasts
Catelas 1998	powders	Macrophages
Mebouta 2000	powders	Human Monocytes
Torricelli 2001	powders	Osteoblasts
Lohman 2002	powders	Osteoblasts

Zirconia: *In-vivo Assays*

Reference	*Physical form*	*Animal model*	*Implant site*
Helmer 1969	Pellets	Monkey	Femur
Hulbert 1972	Porous and non porous disks and tubes	Rabbit	Paraspinal muscle
Garvie 1984	Bars	Rabbit	Paraspinal muscle
Wagner 1986	Pins	Rat	Femur
Christel 1988	Pins	Rat	Paraspinal muscle
Christel 1989	Pins	Rabbit	Femur
Maccauro 1992	Powders	Mice	Intra-peritoneal
Specchia 1995	Pins	Rabbit	Femur
Warashina 2003	Powders	Rat	Calvaria

Zirconia (Zirconium Dioxide, ZrO_2)

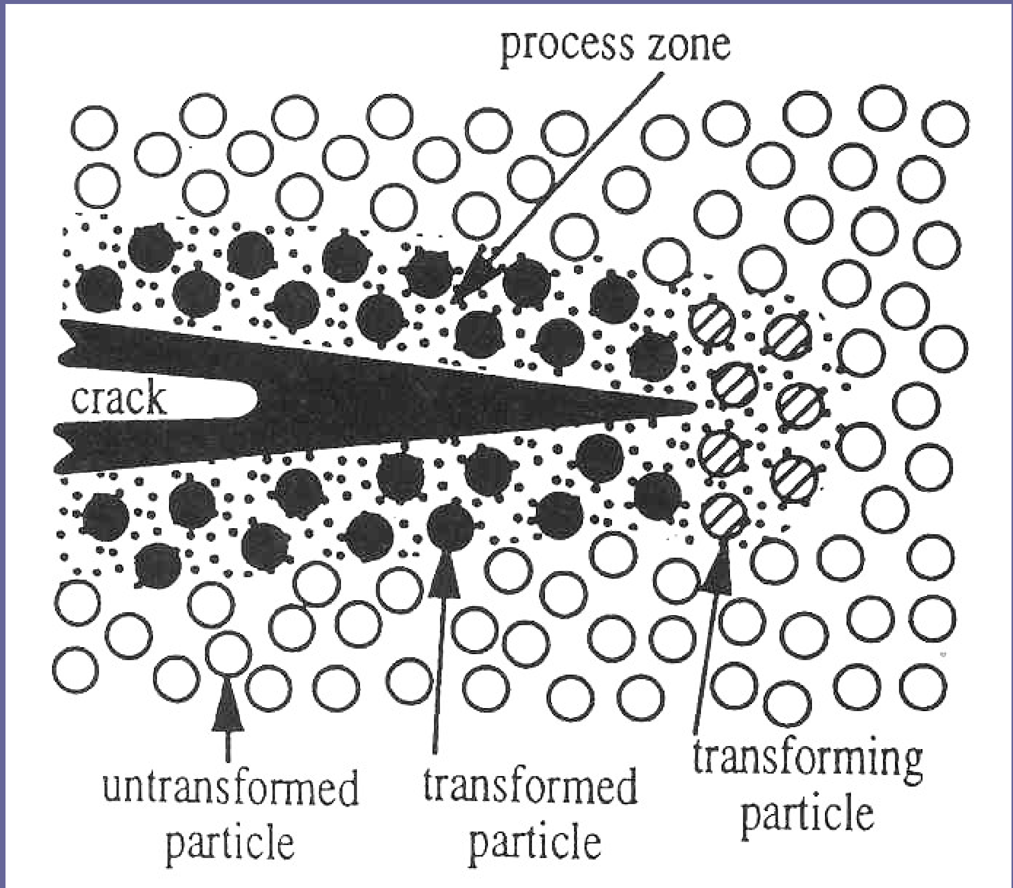


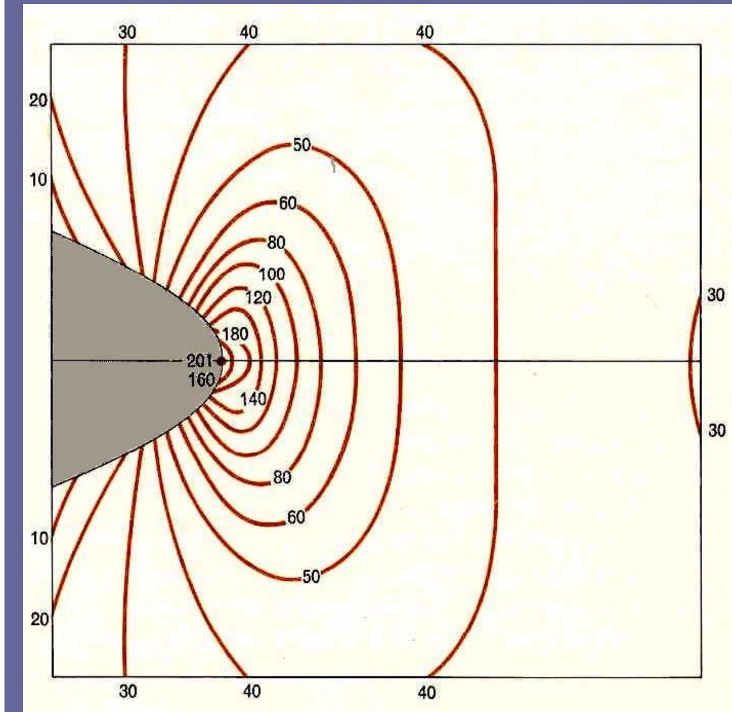
Cubic　　Tetragonal　　Monoclinic

- *Y_2O_3 Yttria*
- *CaO Calcia*
- *MgO Magnesia*
- *CeO2 Ceria*
- *TiO2 Titania*
- …….

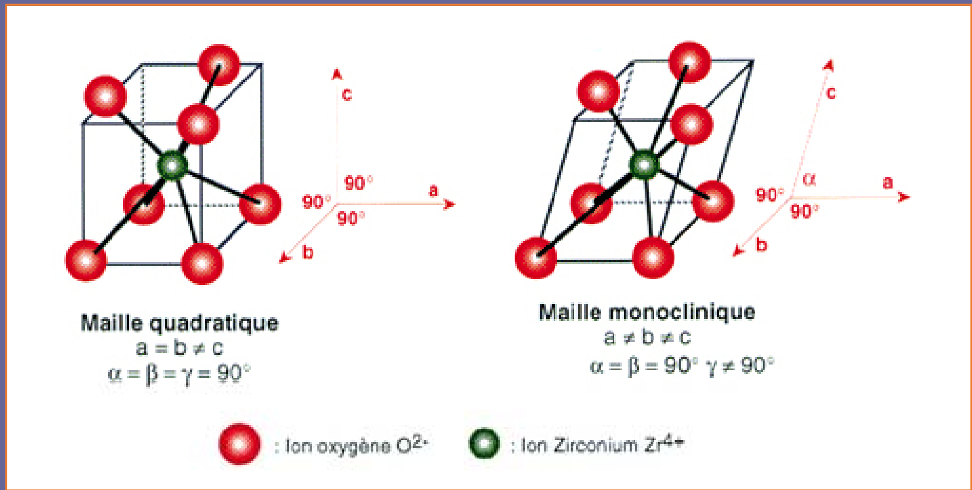
Stabilization to room temperature of the Tetragonal Phase

T-M Phase Transition in Zirconia:
Effective Toughening Process





T-M Phase Transition in Zirconia:
Effective Toughening Process



$$\Delta G_{t\text{-}m} = \Delta G_C + \Delta U_{SE} + \Delta U_S$$

- ΔG_C: Free energy change (temperature, chemical composition)
- ΔU_{SE} : Strain energy change (E matrix, grain size, residual stresses)
- ΔU_S : Change in surface energy (New surfaces, microcracking)

T-M Phase Transition in Zirconia:

Effective Toughening Process

Nature Vol. 258 December 25 1975 703

Ceramic steel?

ZIRCONIUM DIOXIDE (zirconia) has three allotropes: monoclinic, tetragonal and cubic. The transition between the first two involves a large volume expansion which prevents the refractory properties of pure zirconia being used in structural ceramics. The disruptive phase transformation can be suppressed by total stabilisation in the cubic form, but it is generally recognised that the most useful mechanical properties are obtained in multiphase material known as partially-stabilised zirconia (PSZ). Garvie and Nicholson[1] have demonstrated that a fine-scale precipitate of monoclinic zirconia in a cubic stabilised matrix enhances the strength of PSZ. Here we report that a dispersion of metastable tetragonal zirconia in cubic zirconia

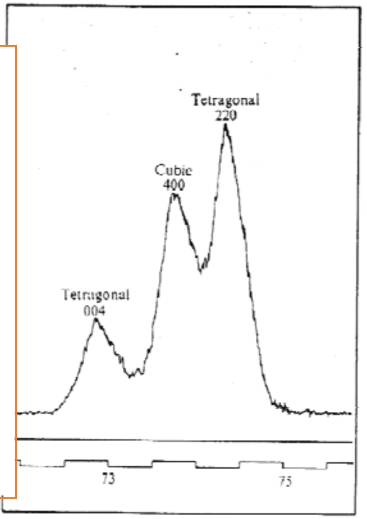


Fig. 1 X-ray diffractometer trace of the {400} peaks showing cubic (400) and tetragonal (004) and (220) reflections. Trace from an as-fired surface of zirconia partially-stabilised with lime (CuKα radiation).

can also be achieved, and that this gives rise to another, more powerful, strengthening mechanism.

The transformation between tetragonal and monoclinic zirconia is believed to be martensitic[2]; it is fast and diffusionless. It is claimed that the tetragonal phase cannot be retained in bulk material to room temperature and atmospheric pressure by any quenching procedure[1,3]. Metastable tetragonal zirconia is known to exist at room temperature only in particles of less than ~ 30 nm diameter; in this case stability is due to the lower surface energy of the tetragonal phase compared with monoclinic[4] (although this explanation is not universally accepted[5]).

Our evidence for the existence of tetragonal zirconia in sintered bodies of lime-stabilised zirconia is extensive. We suspect that the magnesia PSZ material that has been reported to have high strengths[6] would show the same structural features. X-ray diffraction patterns have been obtained from foils thinned by an ion beam and unmachined surfaces, and may be clearly indexed as a mixture of cubic and tetragonal phases (Fig. 1). Transmission electron microscopy of these thinned samples reveals a duplex structure in which second phase particles up to ~ 100 nm in diameter are unambiguously tetragonal (Fig. 2). Carefully prepared samples show no evidence of the monoclinic phase unless the diameter of the second phase is > 100 nm. This conclusion is supported by thermal expansion measurements which exhibit no discontinuity on heating to 1,500 °C; a sudden change in length is normally a sensitive indicator of the presence of monoclinic zirconia (Fig. 3).

The tetragonal phase is metastable and can be transformed readily to monoclinic, for example by diamond grinding the surface or by pulverising during preparation for X-ray powder photographs. The stabilisation of the tetragonal phase is thought to arise from a combination of the surface energy effect discussed above and the constraint of the rigid matrix which opposes the transformation to the less dense monoclinic form[7]. As a result the transformation can occur locally once surface constraints are removed; it is probably triggered by shear strains. The transformation has been observed in thin foils during exposure to the electron beam in an electron microscope.

The presence of a tetragonal phase that can revert to the stable monoclinic form has a number of important consequences. The first is a significant increase in strength. Mean transverse rupture strengths of 650 MPa have been measured in lime-stabilised zirconia deformed in four-point bending. This strength is comparable with the highest values reported for oxide ceramics—in fine grained alumina[8]. By contrast the strength of PSZ containing a purely monoclinic phase is 250 MPa. The increase in strength is achieved by an increase in the work of fracture, up to 500 J m^{-2}, rather than by a reduction of defect size (usually grain size or porosity) as in many other strong ceramics. Part of the increased work of fracture probably arises from a dispersed phase interacting with the crack front, as discussed by Bansal and Heuer[9]. A more important contribution comes from the absorption of energy during the martensitic transformation of tetragonal particles to monoclinic (as in the TRIP steels[10]).

A further contribution to strengthening arises from surface finish. By contrast with other brittle materials, grinding the surface increases, rather than reduces, the strength compared with a polished finish. This difference is associated with an increase in the monoclinic content at the surface on grinding and is illustrated in Table 1. The proportions of the phases recorded there were estimated

Table 1 Influence of surface condition on strength and phase content (determined by X-ray diffraction) of zirconia partially stabilised with lime

	Transverse rupture stress (± s. d.) (MPa)	FWHM (111 cubic peak) (2θ)	% monoclinic at surface ({111} peaks)	% tetragonal at surface ({400} peaks)
As-fired	Not determined	0.22°	0	53
Diamond ground	600 ± 11	0.46°	17	36
Ground and polished	490 ± 30	0.35°	9–12	41
Ground and annealed for 1 h at 850 °C	500	0.36°	16	37

Nature Vol. 258 December 25 1975

Ceramic steel?

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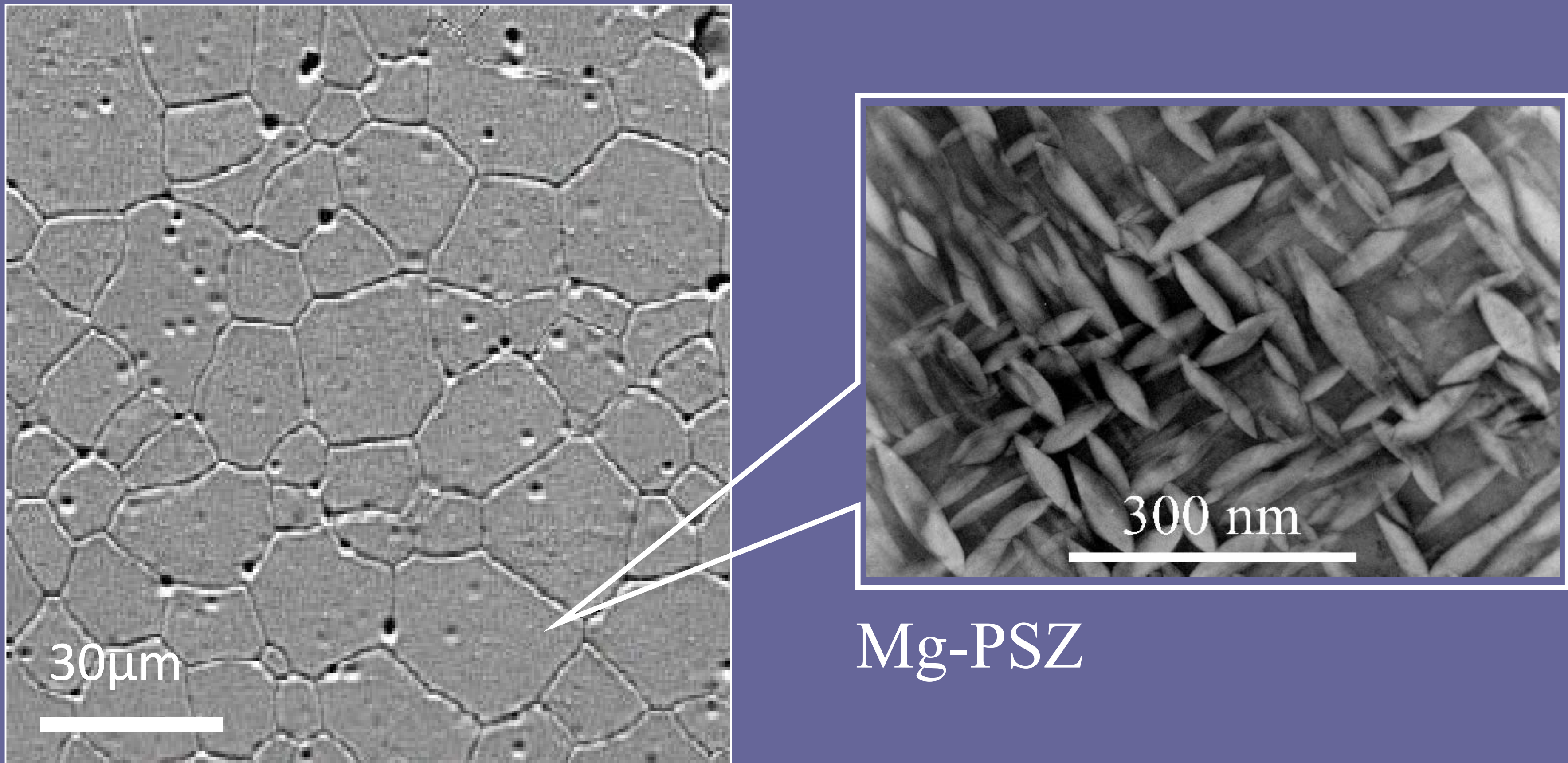
Partially Stabilized Zirconia – PSZ

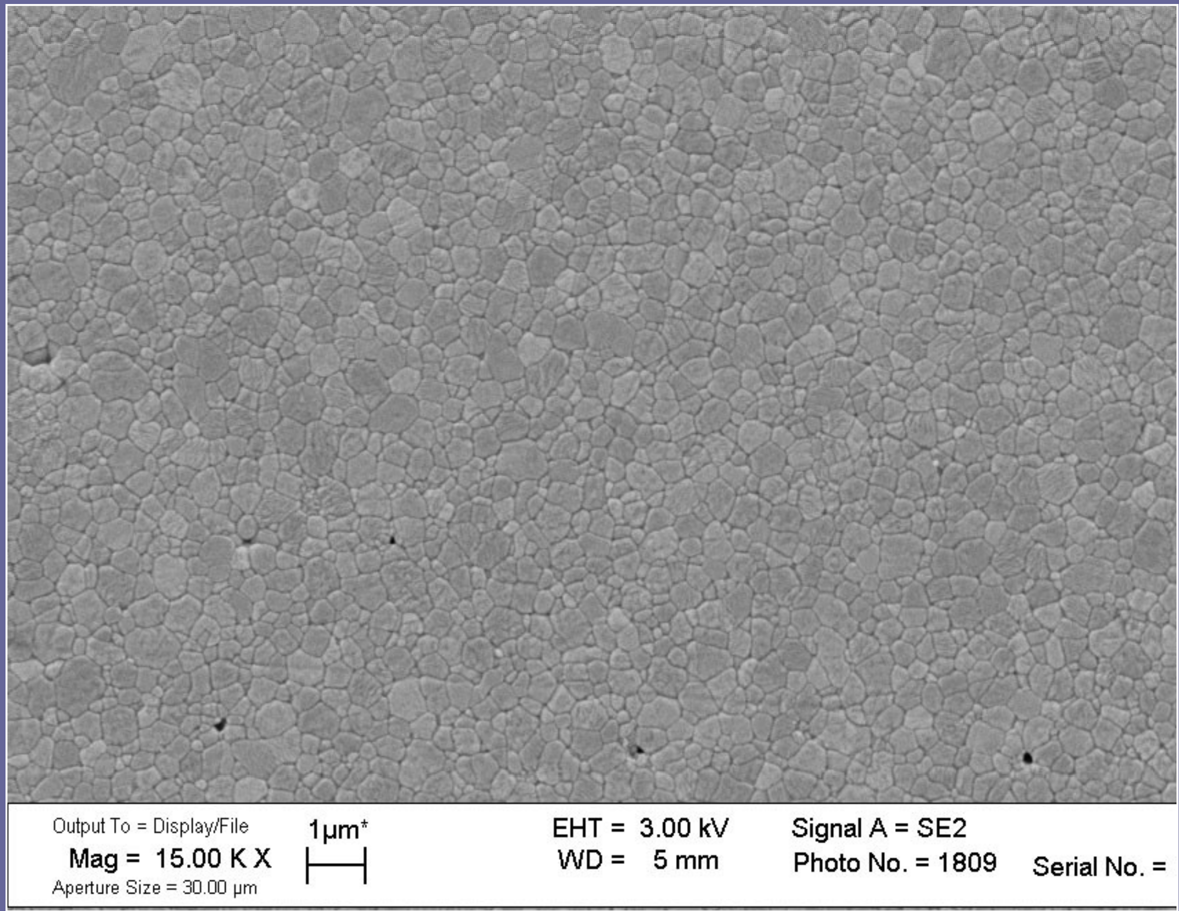
Garvie, 1975



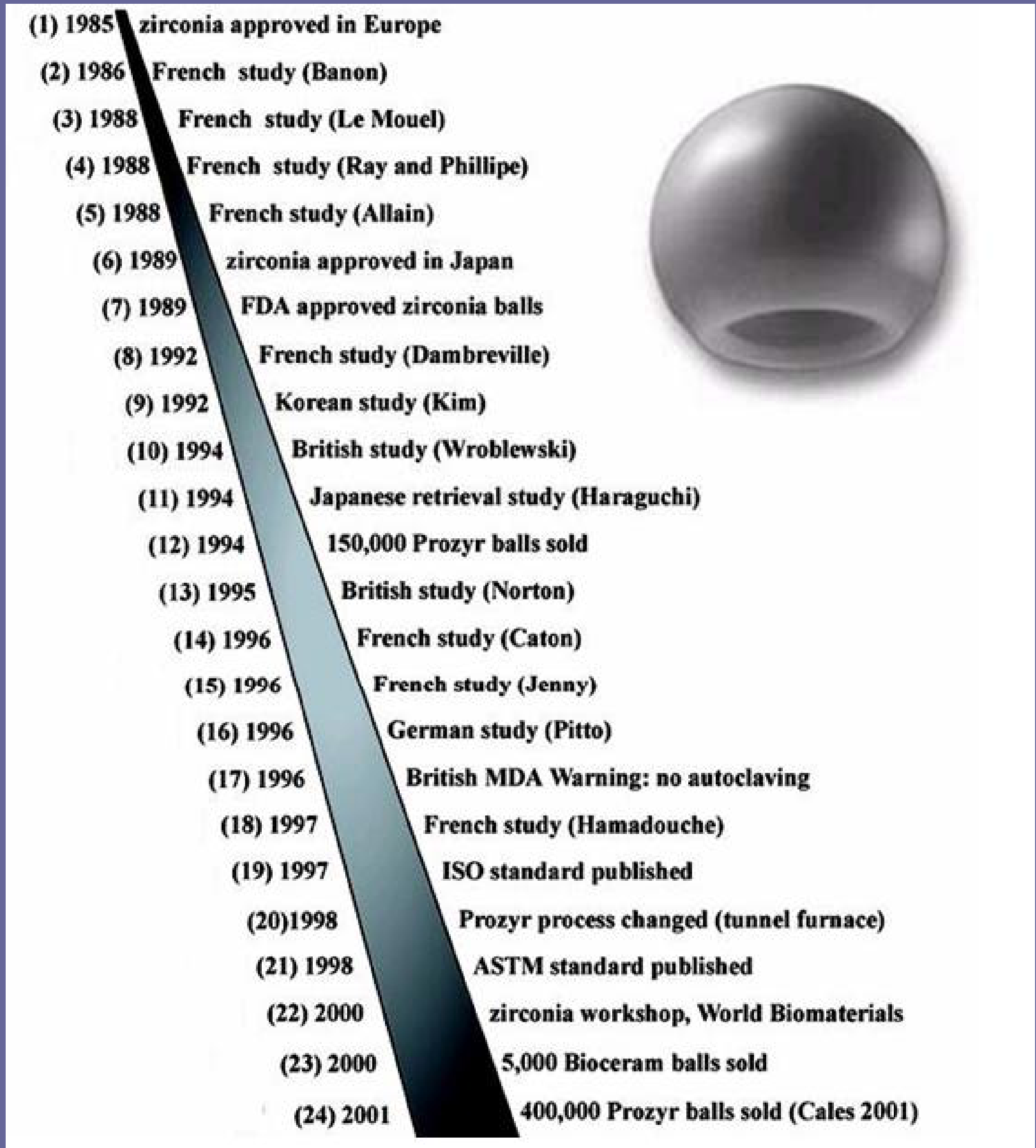
Mg-PSZ

Tetragonal Zirconia Polycrystal - TZP

Gupta, 1977



Zirconia: the Alternative to Alumina (?)



(Clarke I, et al 2006)

Zirconia Vs. Alumina Behavior

Property	Unit	Alumina	Y-TZP	Z/A ratio
Density	g/ cm^3	3.98	6.08	1.53
Bending Strength (4p)	MPa	650	1100	1.7
Toughness (SEVB)	MPa $m^{1/2}$	4	8	2
Elastic Modulus	GPa	380	210	0.55
Hardness	HV	2000	1200	0.6
Thermal Conductivity (25°C)	W/ mK	30	2.5	0,08

Manufacturers of zirconia ball heads

Name	Country	Notes
SGCA Desmarquest	F	Prozyr®
Cerasiv	D	Ziolox®
Morgan Matroc	UK	Ziranox®
Ceraver	F	*Experimental*
HTI Technologies	F	Biozyr®
Metoxit	CH	Bio-Hip®
Coors	USA	*Experimental*
Kyocera	J	Bioceram®
AstroMet	USA	*Experimental*

Zirconia Vs. Alumina Behavior

No Ceramic on Ceramic Bearings

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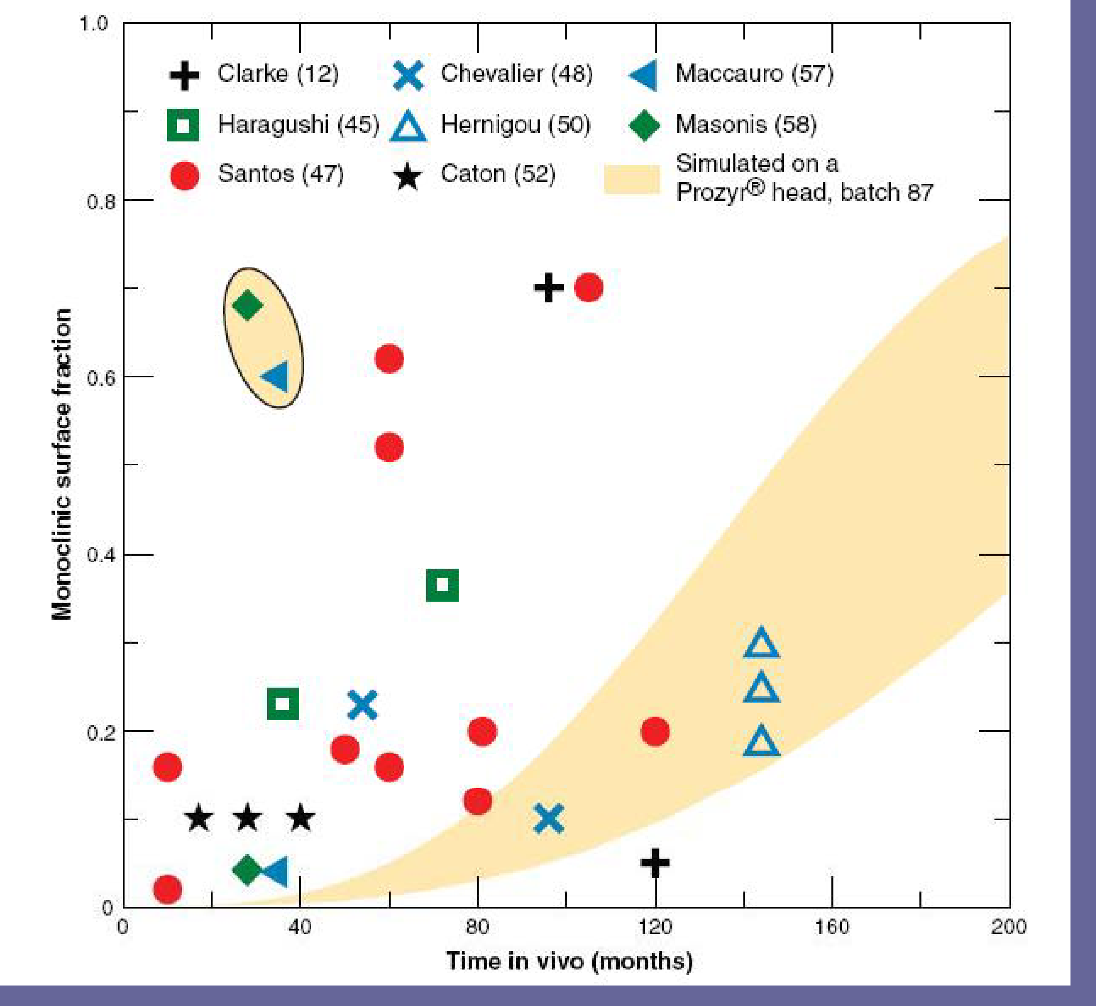
Hardness	HV	2000	1200	0.6
Thermal Conductivity (25°C)	W/ mK	30	2.5	0,08

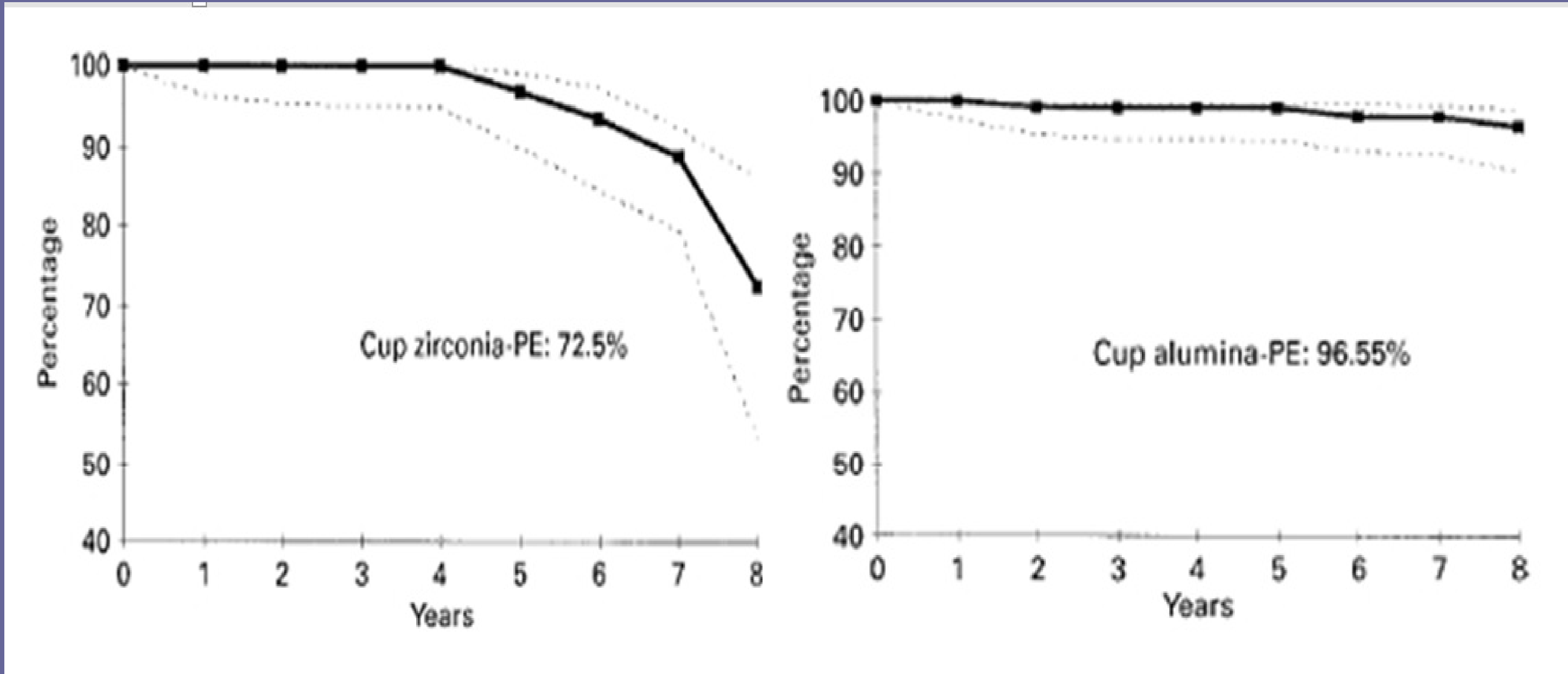
Zirconia: Low Temperature Degradation (LTD)

Chevalier J, Gemillard L, Deville S, 2007

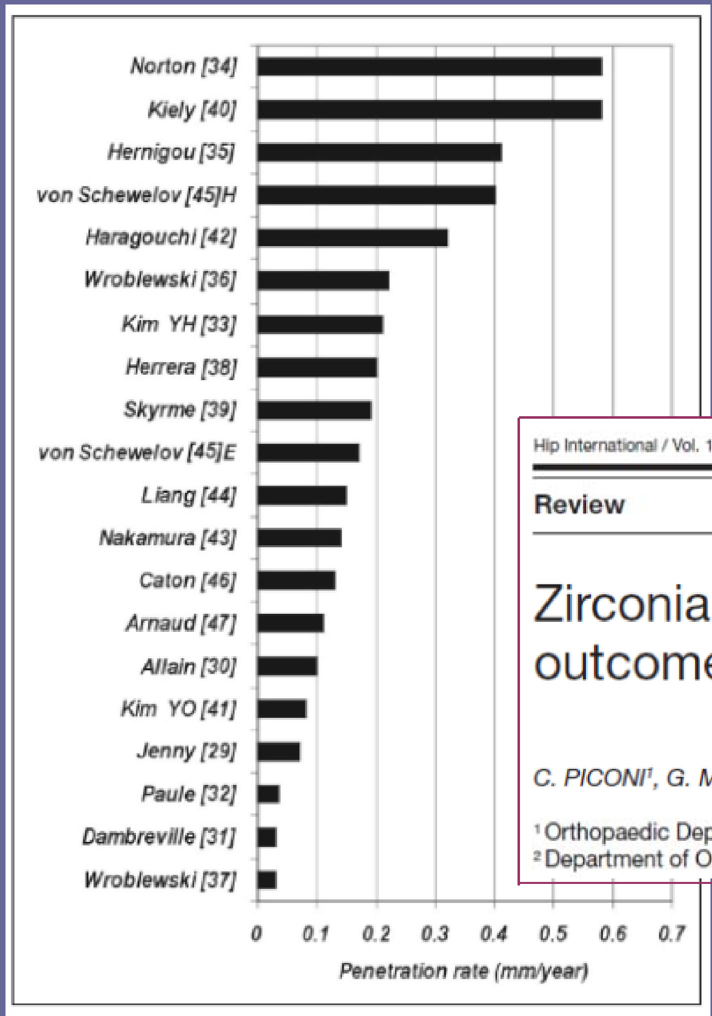


Zirconia/PE Vs. Alumina/PE THR Bearings

Implant Survival (Allain, et al., 1999)



Zirconia/PE THR Bearings:
Head Penetration Rates



Hip International / Vol. 17 no. 3, 2007 / pp. 119-130
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Review

Zirconia heads in perspective: a survey of zirconia outcomes in total hip replacement

C. PICONI[1], G. MACCAURO[1], M. ANGELONI[1], B. ROSSI[1], I.D. LEARMONTH[2]

[1] Orthopaedic Department, Catholic University of Rome, Rome - Italy
[2] Department of Orthopaedic Surgery, University of Bristol, Bristol - UK

Zirconia:The Prozyr® recall

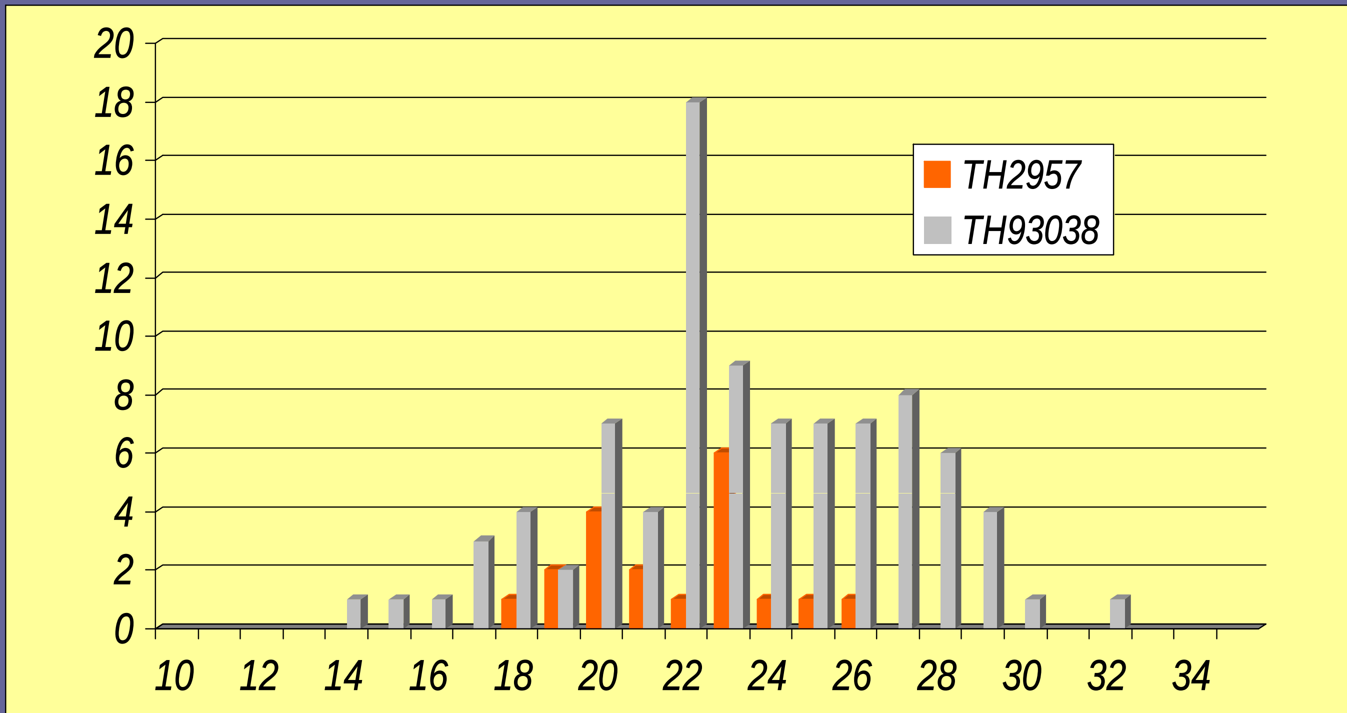
YTZP – Saint Gobain Advanced Ceramics

U.S. Food and Drug Administration

C·D·R·H *Center for Devices and Radiological Health*

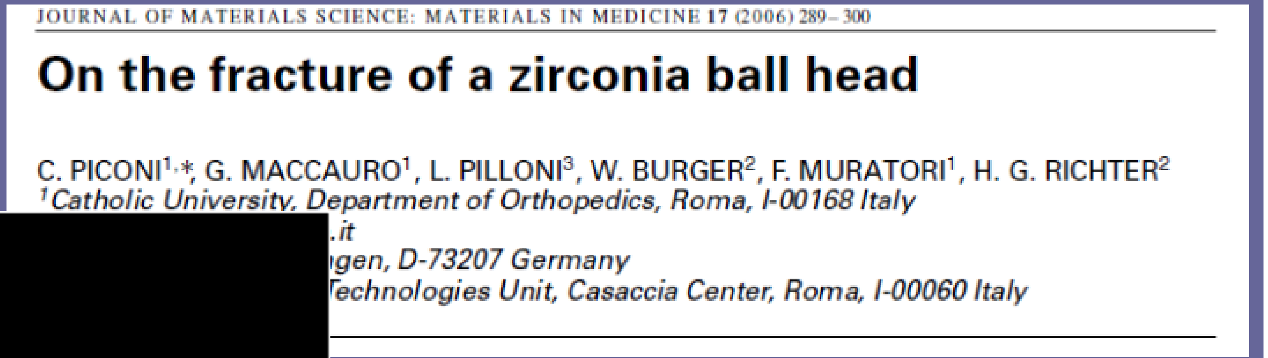
Medical Device Recalls 2001

Recall of Zirconia Ceramic Femoral Heads for Hip Implants



(AFSSAPS data - 162 Ball heads)

Clinical Case, (fractured 34 months postop)


JOURNAL OF MATERIALS SCIENCE: MATERIALS IN MEDICINE 17 (2006) 289 – 300

On the fracture of a zirconia ball head

C. PICONI[1,*], G. MACCAURO[1], L. PILLONI[3], W. BURGER[2], F. MURATORI[1], H. G. RICHTER[2]
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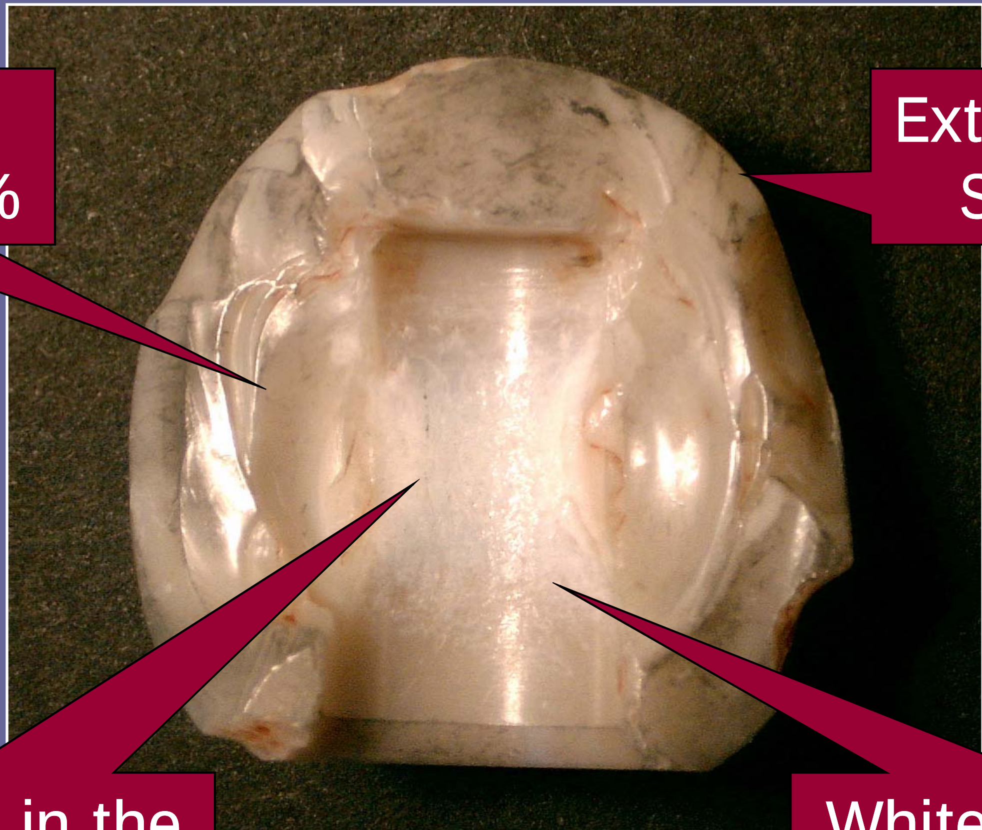
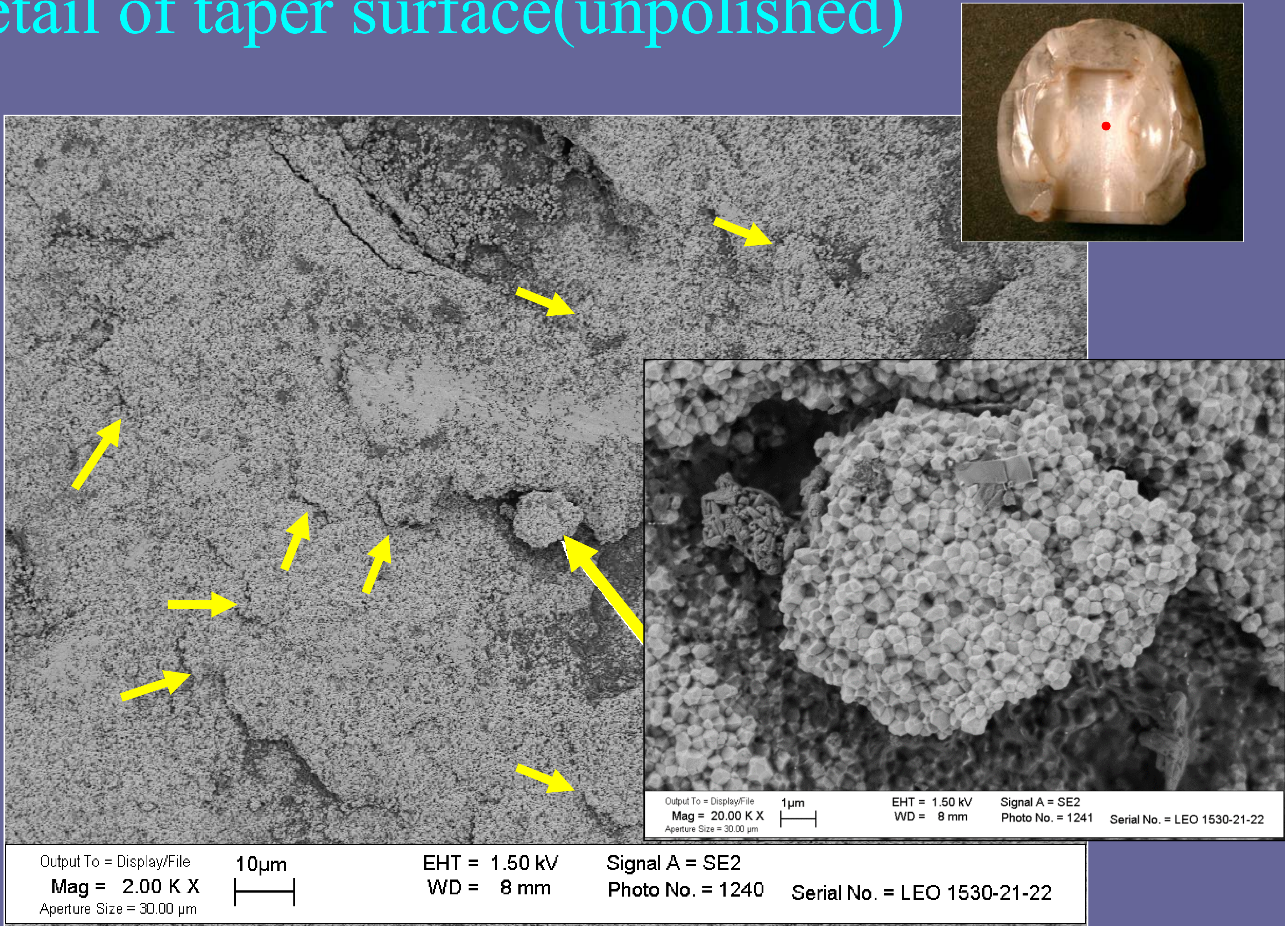
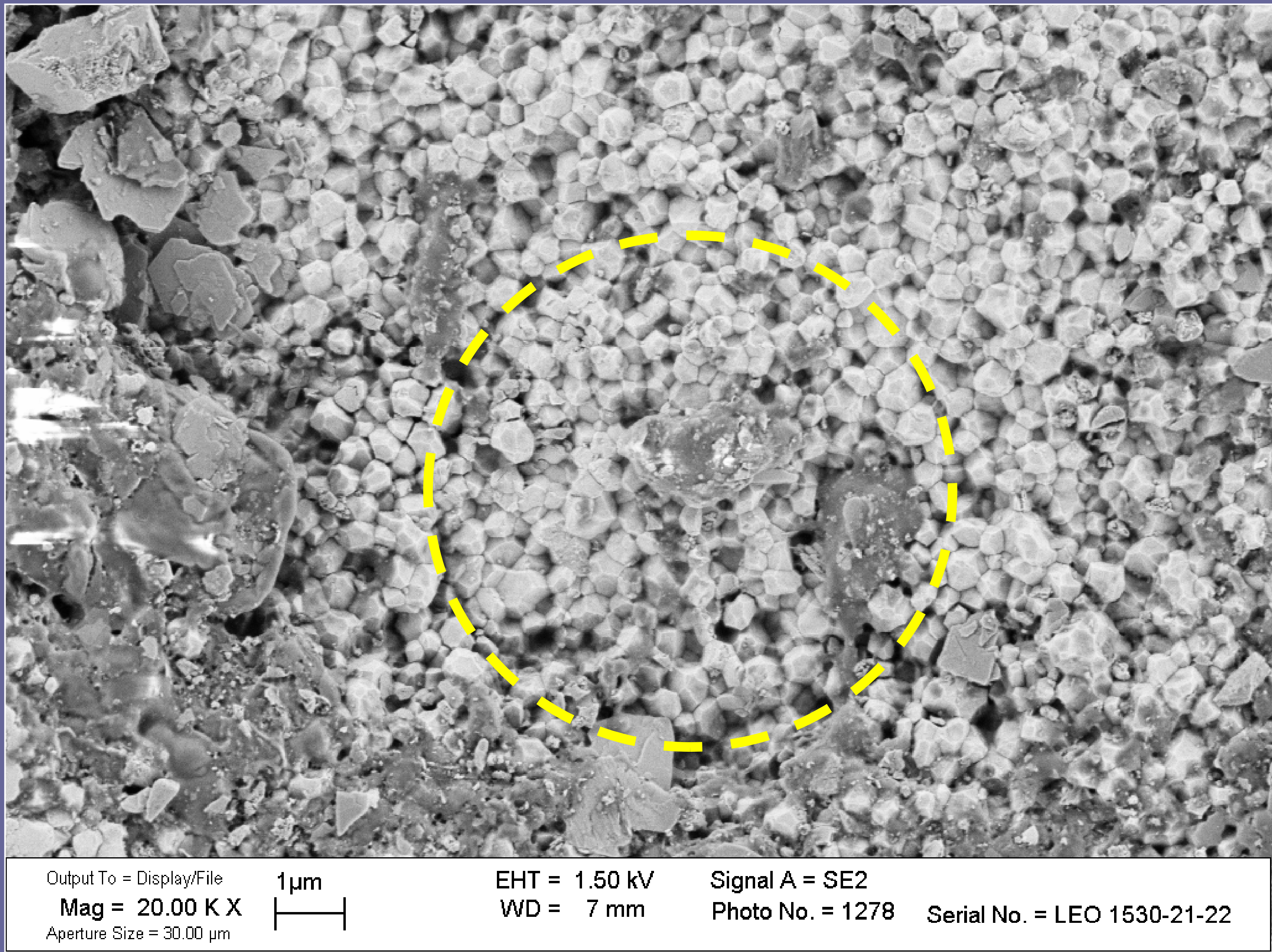
.it
gen, D-73207 Germany
Technologies Unit, Casaccia Center, Roma, I-00060 Italy

XRD Results – Monoclinic Phase

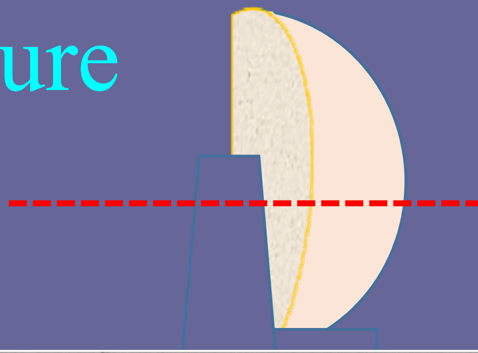


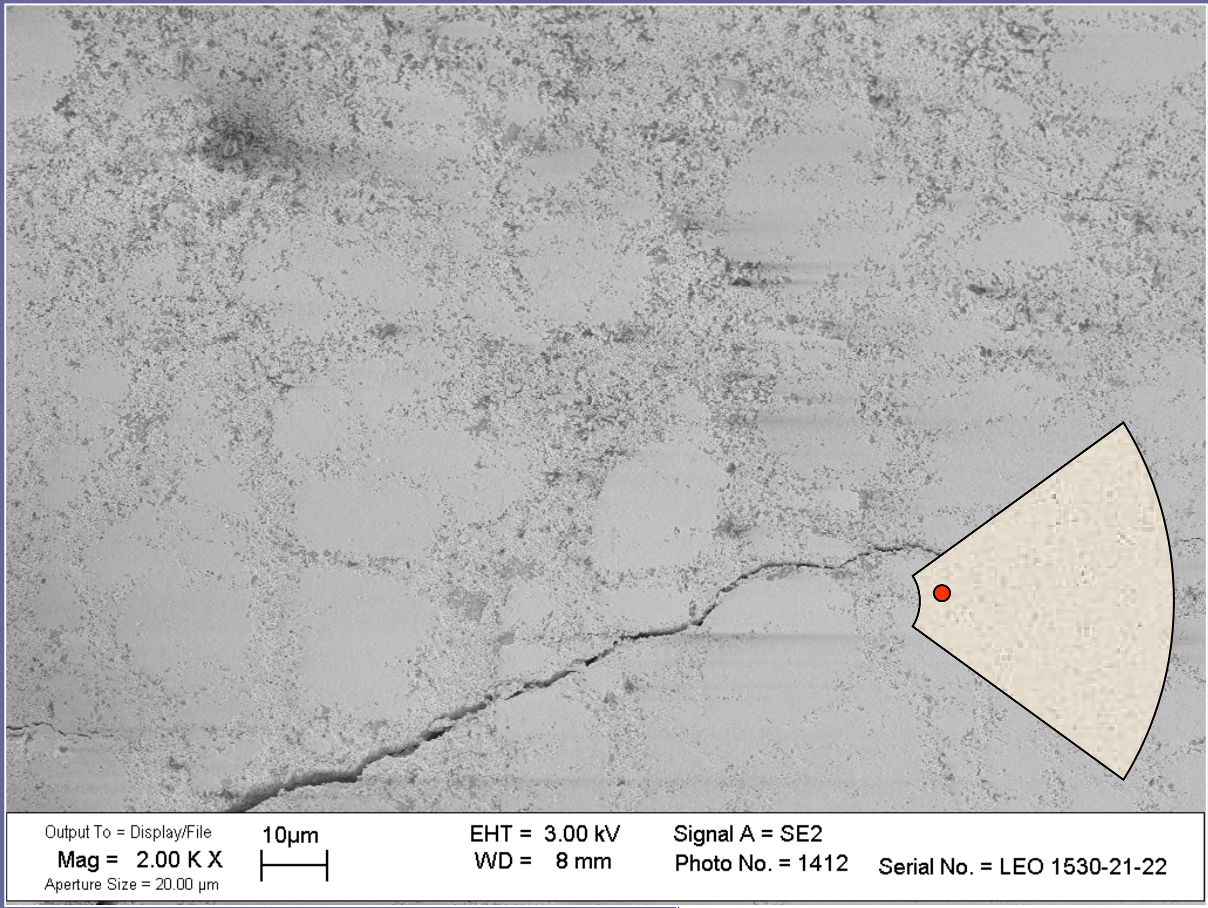
Detail of taper surface(unpolished)

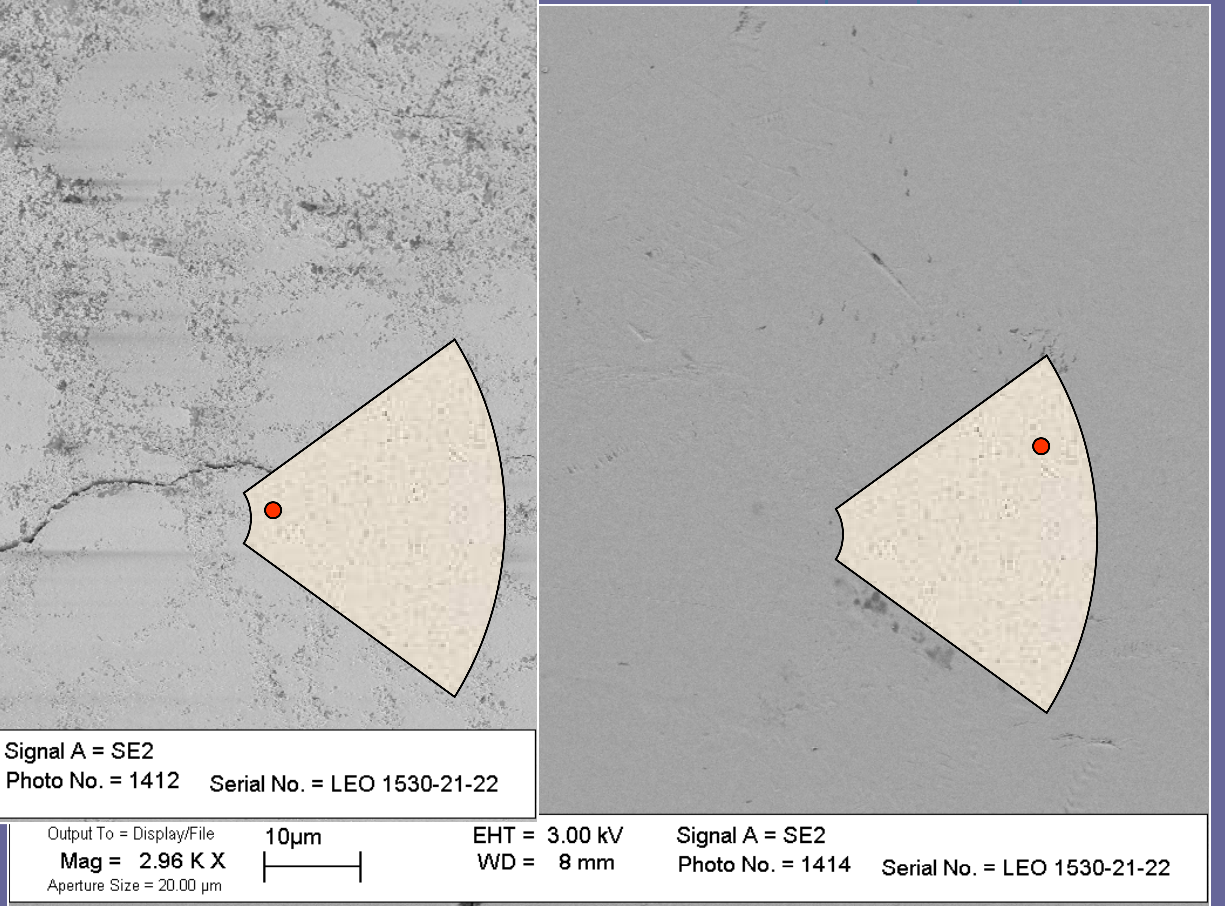



Output To = Display/File
Mag = 20.00 K X
Aperture Size = 30.00 µm
1µm
EHT = 1.50 kV
WD = 7 mm
Signal A = SE2
Photo No. = 1278
Serial No. = LEO 1530-21-22

Head Inner Vs. Outer Microstructure

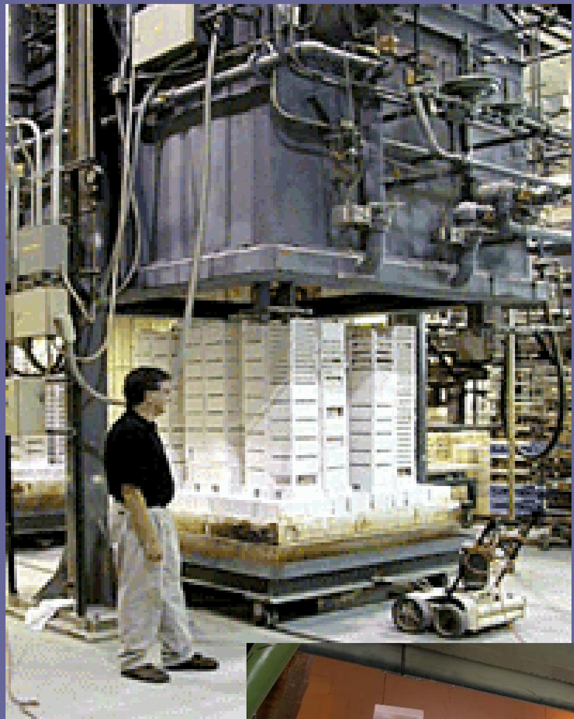


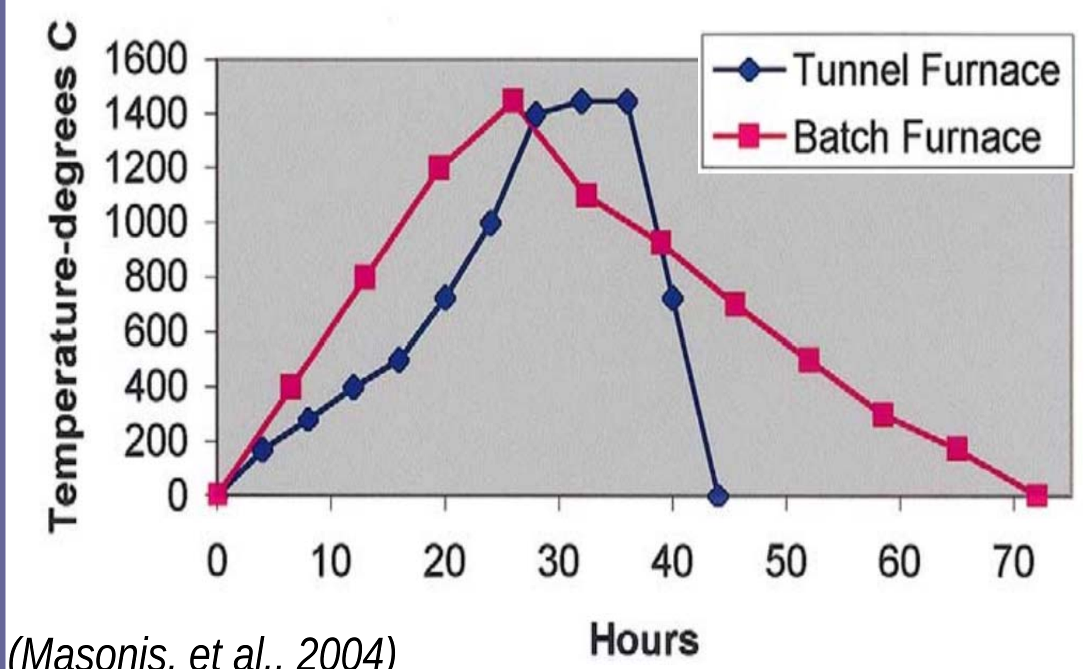




Zirconia:The Prozyr® recall:

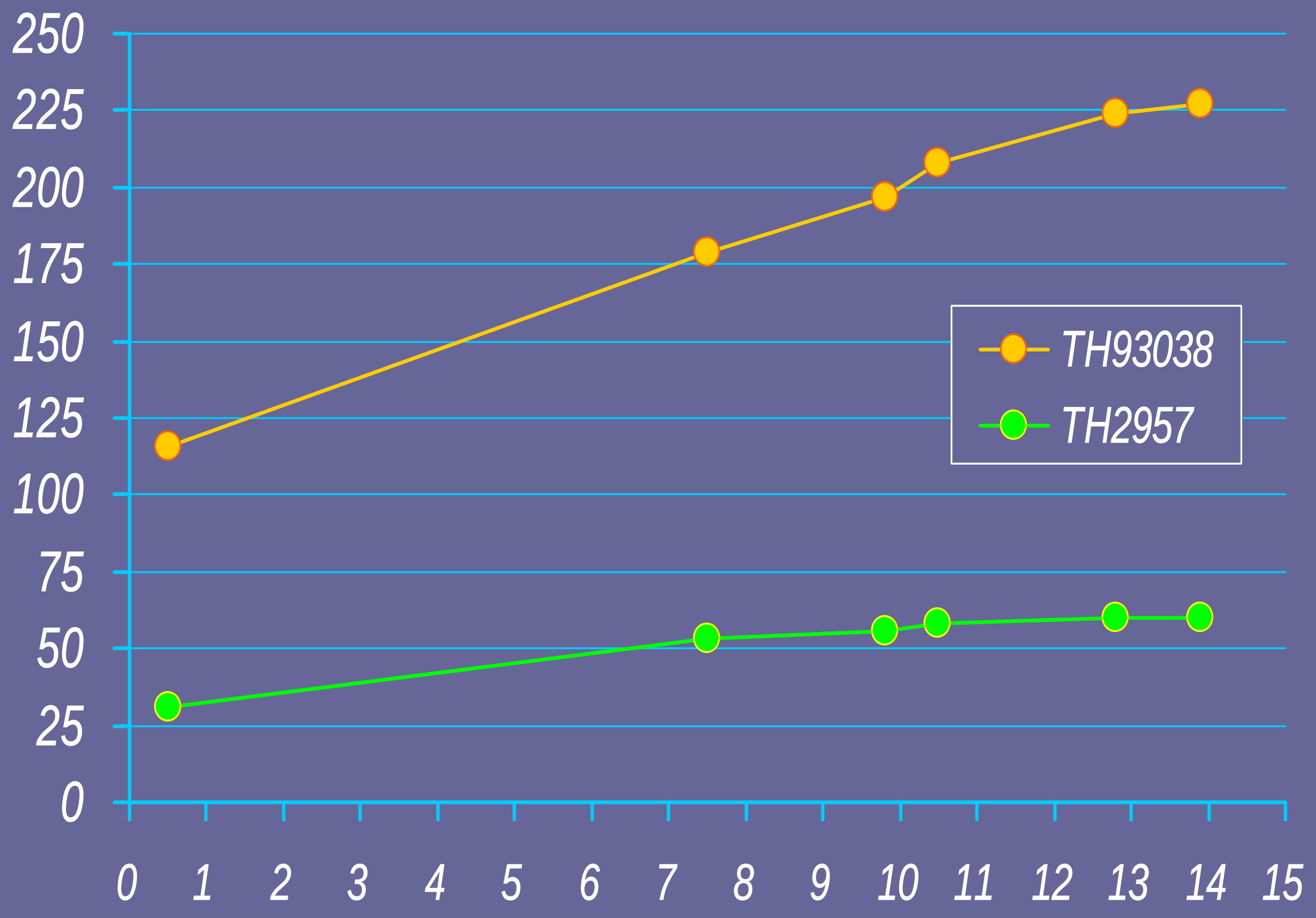
Batch Vs.tunnel ovens





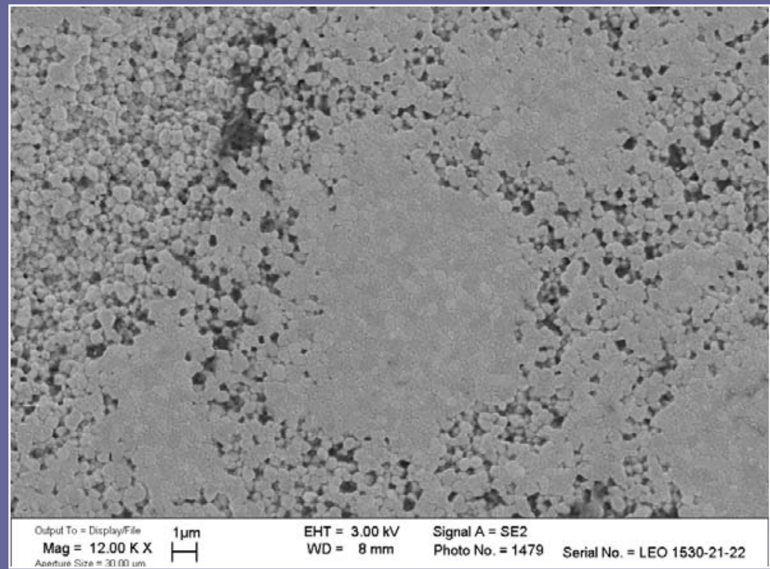
(Masonis, et al., 2004)

Prozyr® fractures Jan 2002 – Jan 2003



(data from: www.prozyr.com)

Remarks on the case



- The likely initiator of the ball head fracture is the unproper process control during sintering
- Due to lack of densification of the core, fracture started due to subcritical crack growth at taper surface
- The phase transformation observed in the inner parts of the ball head had little effect on the failure

Zirconia in Arthroplasty

Summary

- Pros
  - Optimum Biological Safety
  - Optimum Strength
- Cons
  - Low Hardness, Low Thermal Conductivity
  - Ceramic-on-Poly Bearings Only
  - Risk of Low Temperature Degradation
  - Critical Manufacturing Process

ALUMINA:

PROS:
Optimum biocompatibility
Good strength

CONS:
Brittle fracture mechanics
Limitation in device design

ZIRCONIA:

PROS:
Optimum biocompatibility
Optimum strength

CONS:
No CoC joints
Risk of LTD

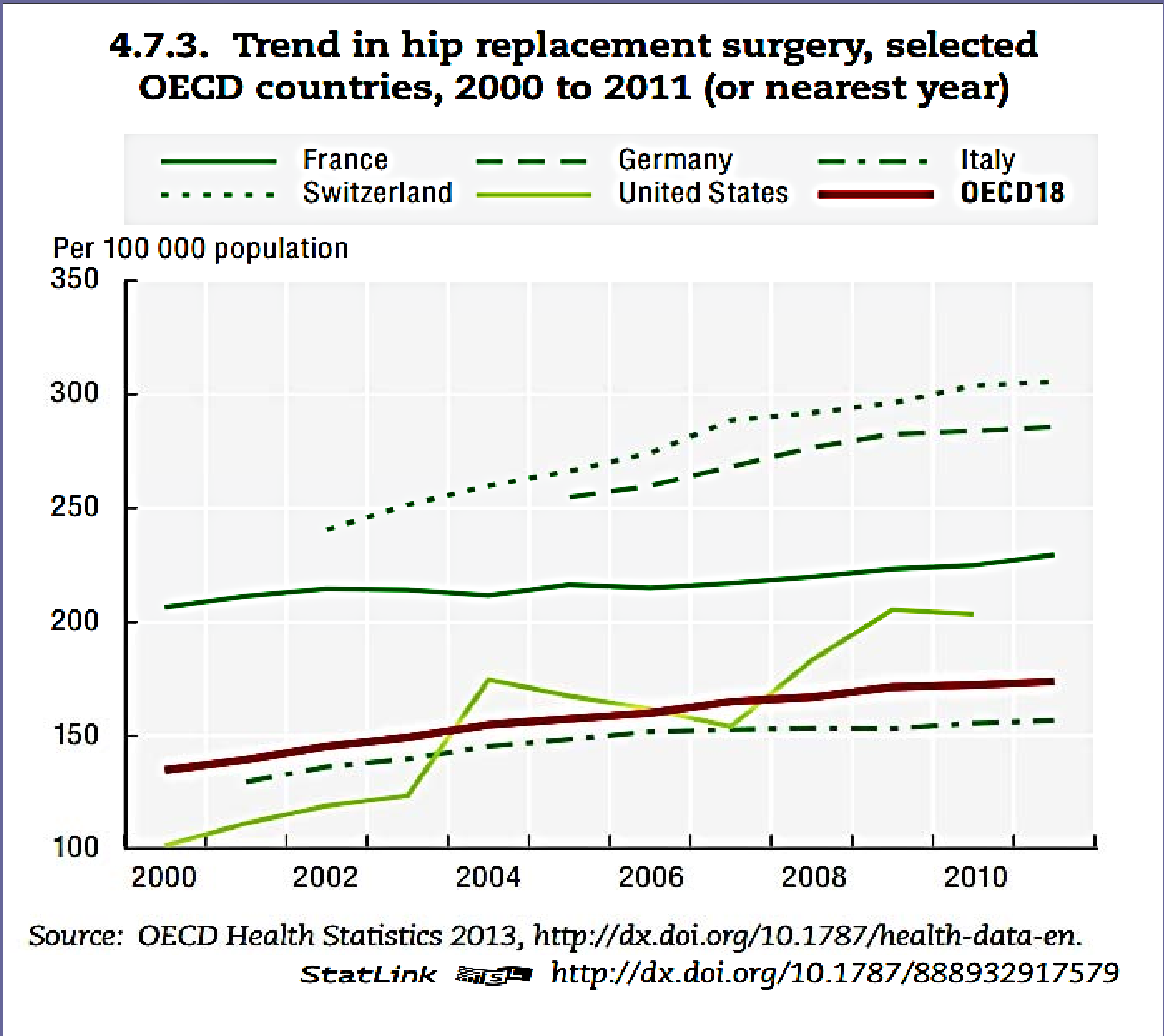
Demand of a New Material:

Biocompatible as Alumina or Zirconia
As Tough and Strong as Zirconia
Stable in-vivo for Long Time as Alumina
Excellent in Tribology as Alumina
Flexible in Device Design

Summary

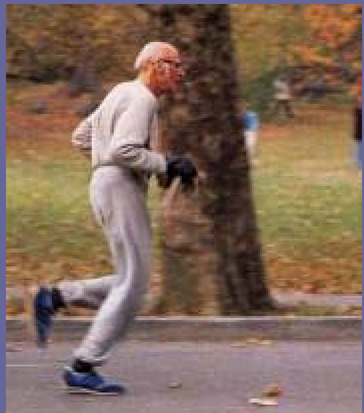
- The Precursors
- 1970s : The Pioneers
- 1980 – 2004: The Development
  - Alumina
  - Zirconia
  - ZTA – ATZ composites
- Bioceramics in Hip Joint Replacements Today

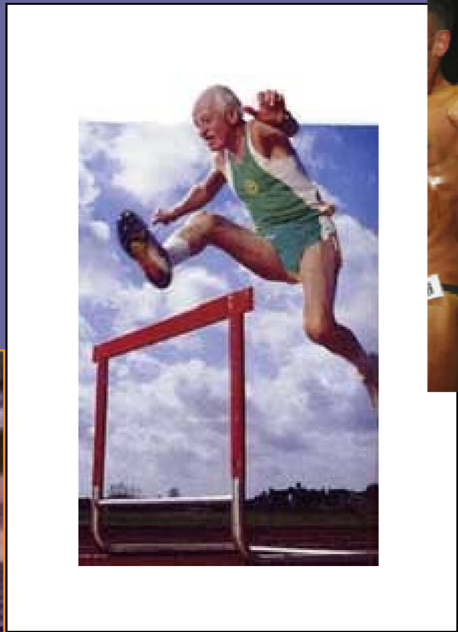
THR Demand by the early 2000s'

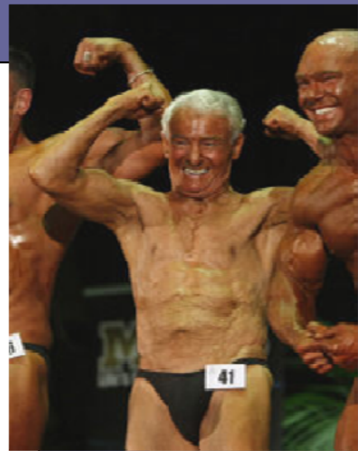


Increase in Demand for THR Bearings

More "Young & Active" Patients….







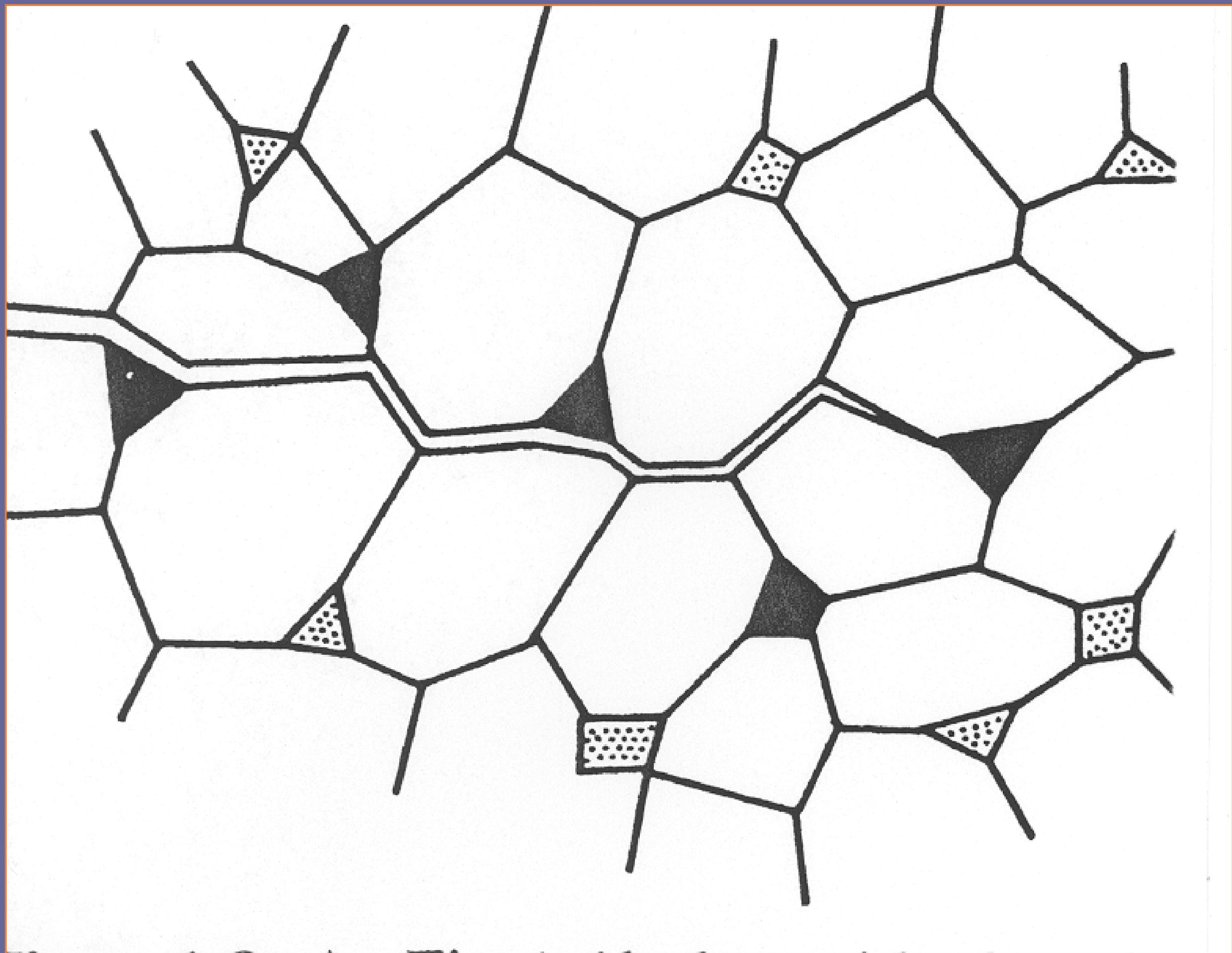
Why a New Material ?

Demand of New Devices by the year 2000

- Ball heads necks XL, XXL
- Ball heads Ø 7/8” (22,22 mm)
- CoC joints > Ø 36mm (thin walled inserts)
- Ceramic knee replacements
- Ceramic revision heads (thin walled)
- New devices for spine & small joints
- ……..

What a New Material ?

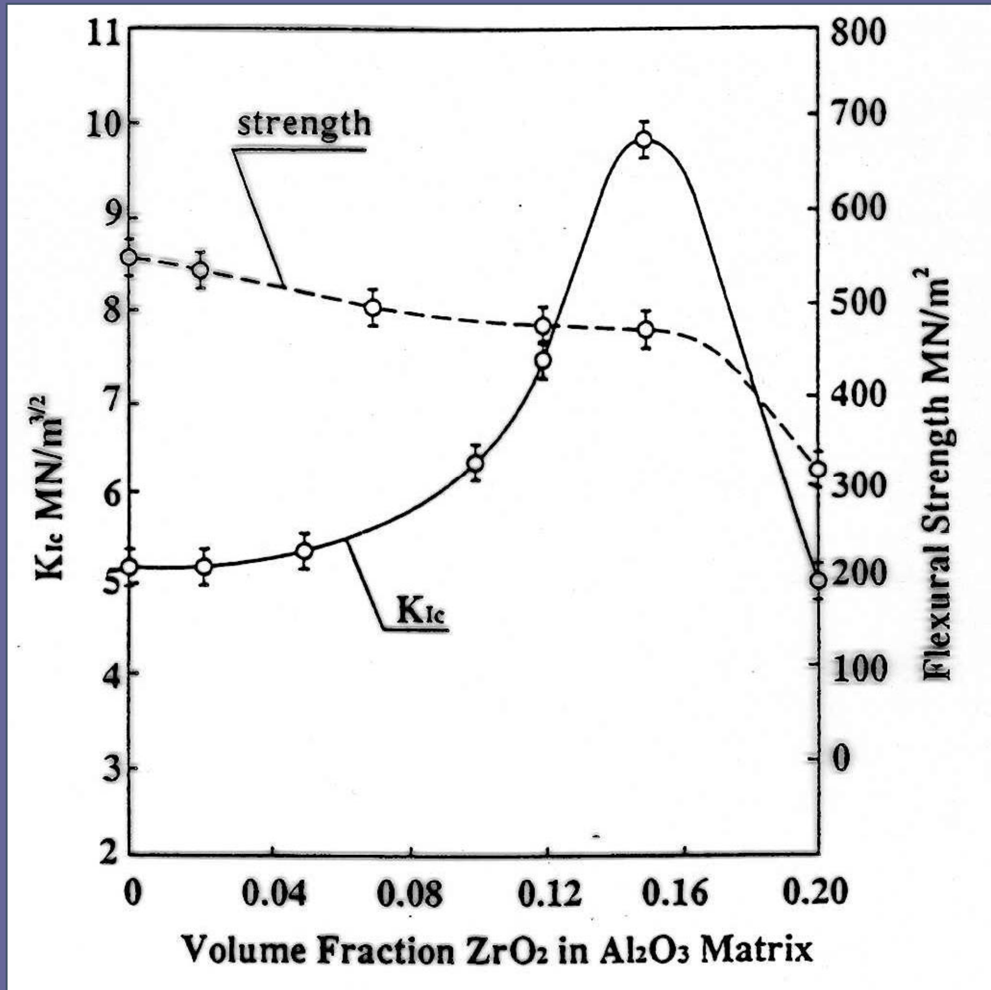
Toughened by a transformable phase



Zirconia-Toughened Alumina (ZTA)

1976:
Claussen,
J Am Ceram Soc

1977:
Dworak, Olapinski,
German Patent DE2744700



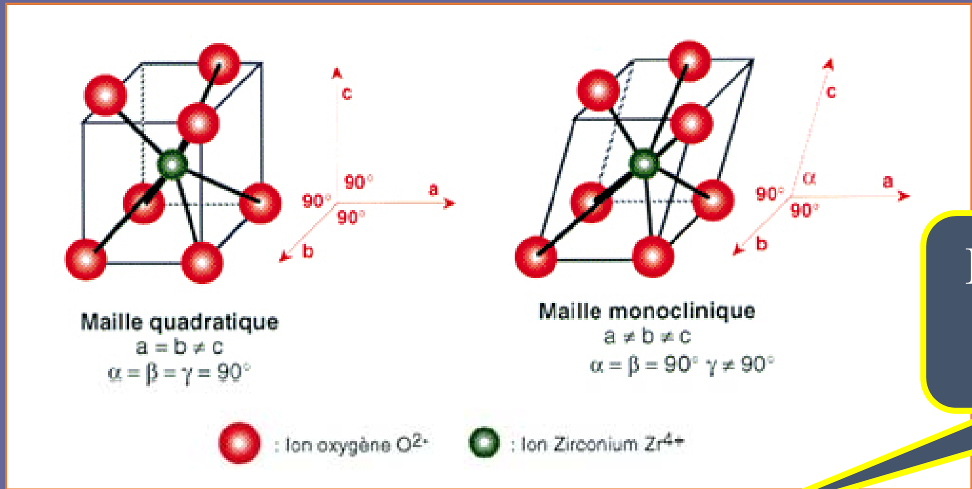
ZTA as Biomaterials

The French Program	1990	Mandrino A, et al.	In-vivo ageing tests Pin-on-flat wear tests
	1991	Ben Abdallah A, Treheux D	Pin-on-Flat & Cylinder-on-Flat Wear Tests
	1992	Mandrino A, et al.	Tissue response to ZTA implants

The Italian Program (Σ 294)	1994	Salomoni A, et al.	Manufacture of ball heads by slip casting
	1999	Affatato S, et al.	Ball heads wear tests (hip simulator)
	2000	Ciapetti E, et al.	In-vitro assays (extracts and wear debris)

Rationale for A/Z composites

Phase Transformation Toughening



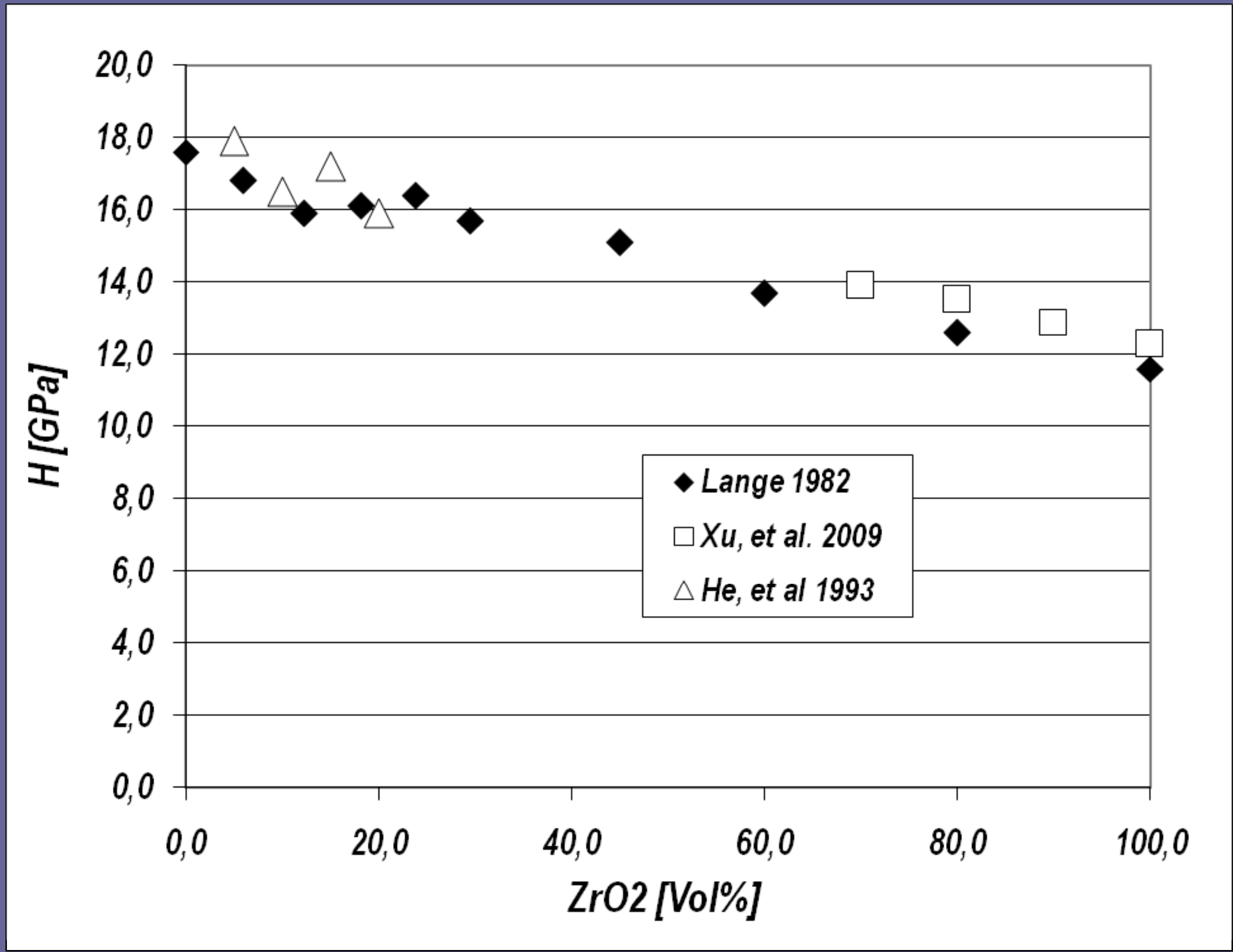
$E_{alumina}$ = 380 GPa
$E_{zirconia}$ = 200 GPa

$$\Delta G_{t\text{-}m} = \Delta G_C + \boldsymbol{\Delta U_{SE}} + \Delta U_S$$

- ΔG_C: Free energy change (temperature, chemical composition)
- ΔU_{SE} : Strain energy change (E matrix, grain size, residual stresses)
- ΔU_S : Change in surface energy (New surfaces, microcracking)

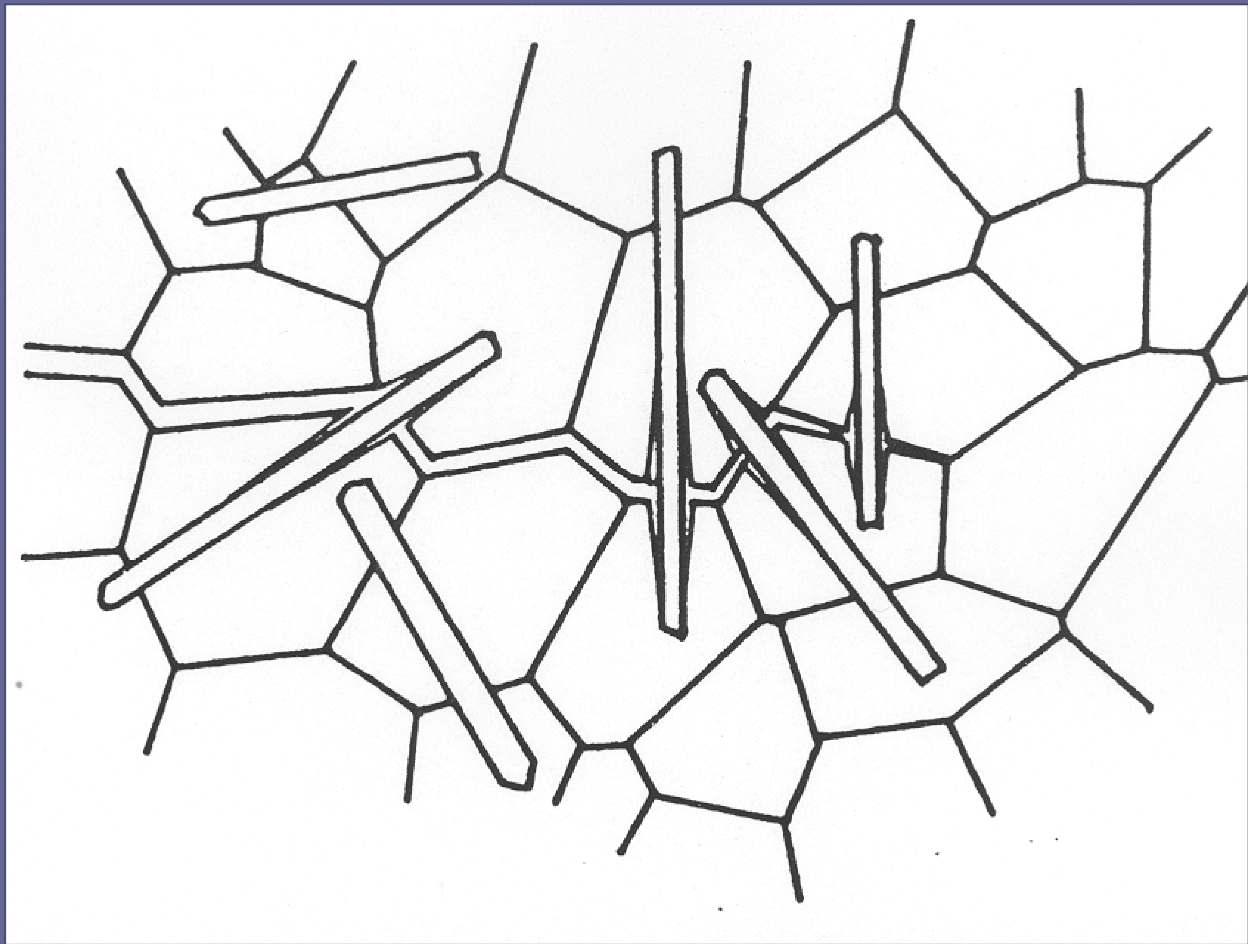
Zirconia Toughened Ceramics (ZTCs)

Hardness Vs. Zirconia vol%



What a New Material?

Toughened by a fiber-like phase

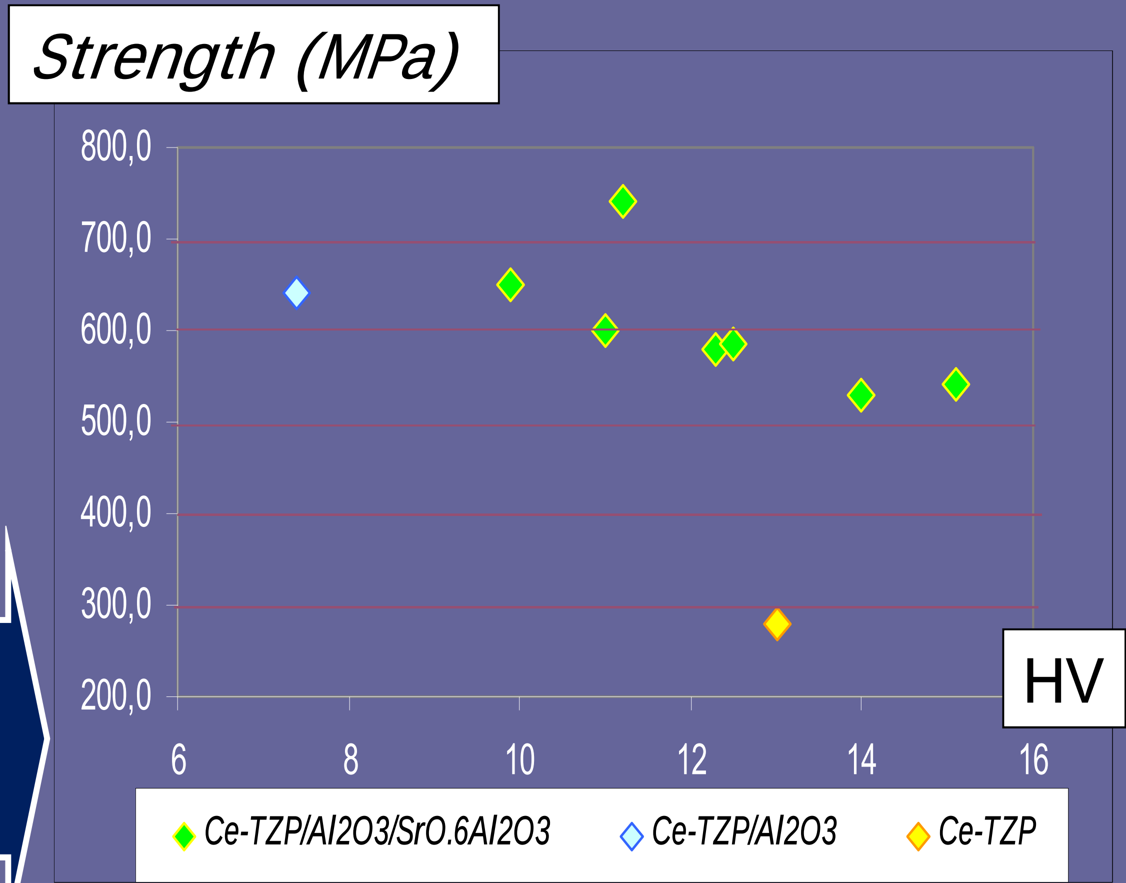


Zirconia/Platelet Reinforced Alumina:

1991, Cutler RA, et al.

Ce-TZP + Al2O3 + Sr

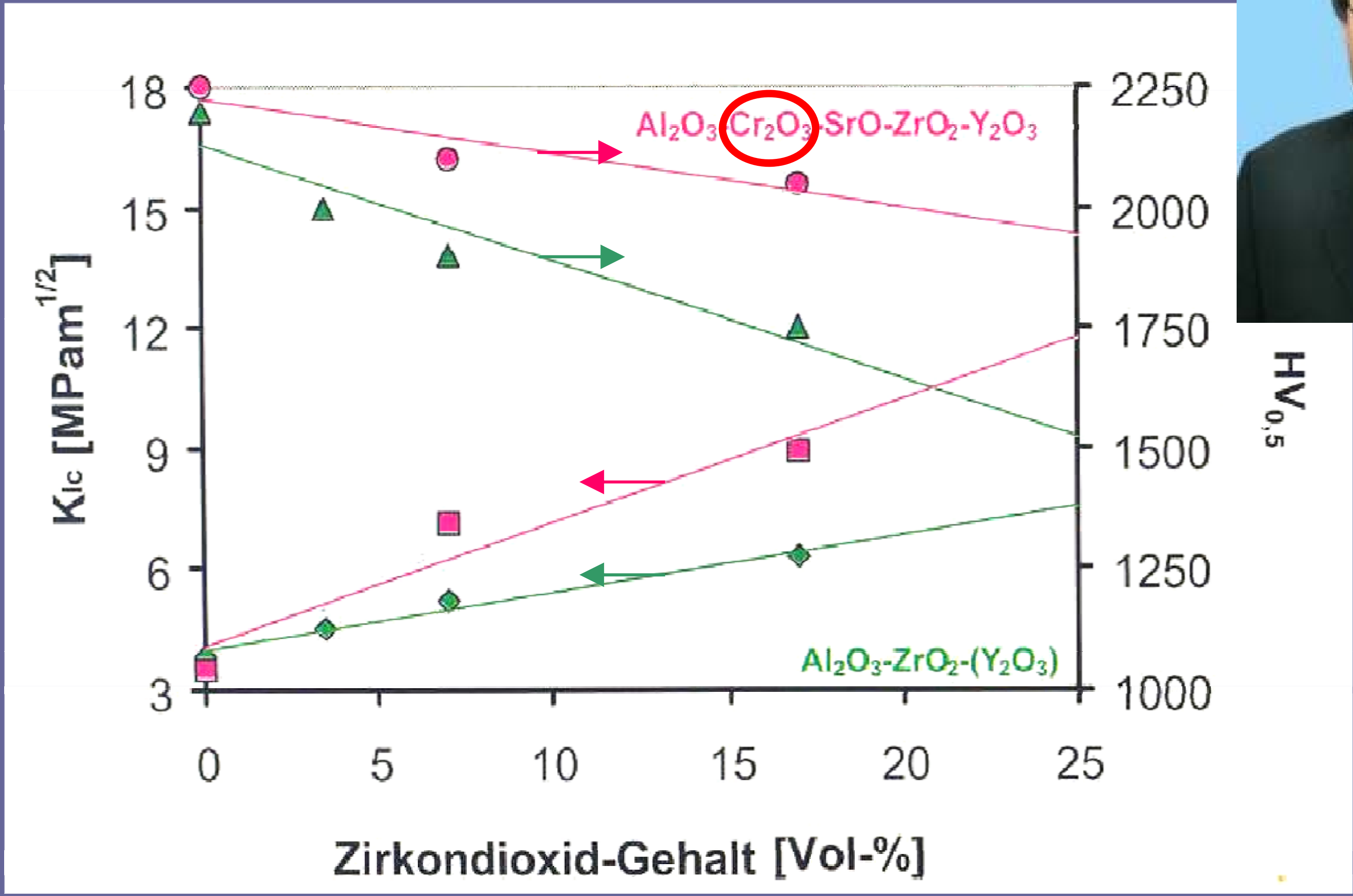
$SrAl_{12}O_{19}$ platelets
0,5 µm x 5-10 µm



Incresed Strength
BUT
Still Low Hardness

Zirconia/Platelet Reinforced Alumina

1998, Burger W, et al.

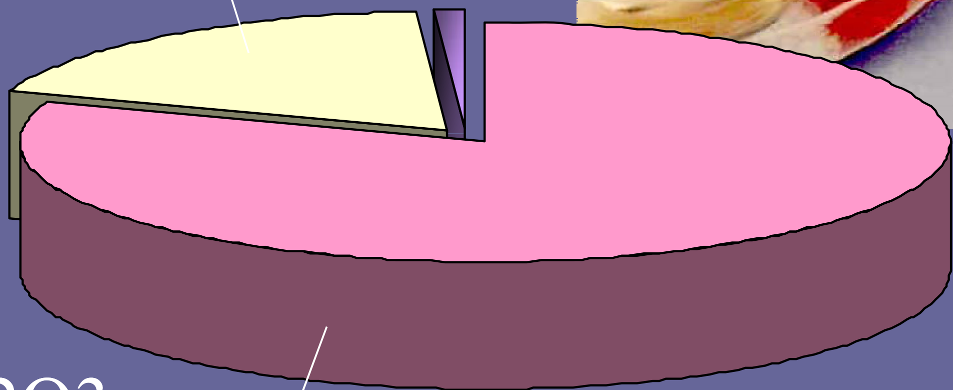


BIOLOX®delta

Composition

Strontium Aluminate Platelets 1-2 vol%

Zirconia YTZP 17 vol%



Alumina + Cr_2O_3

BIOLOX®delta features

Matrix:

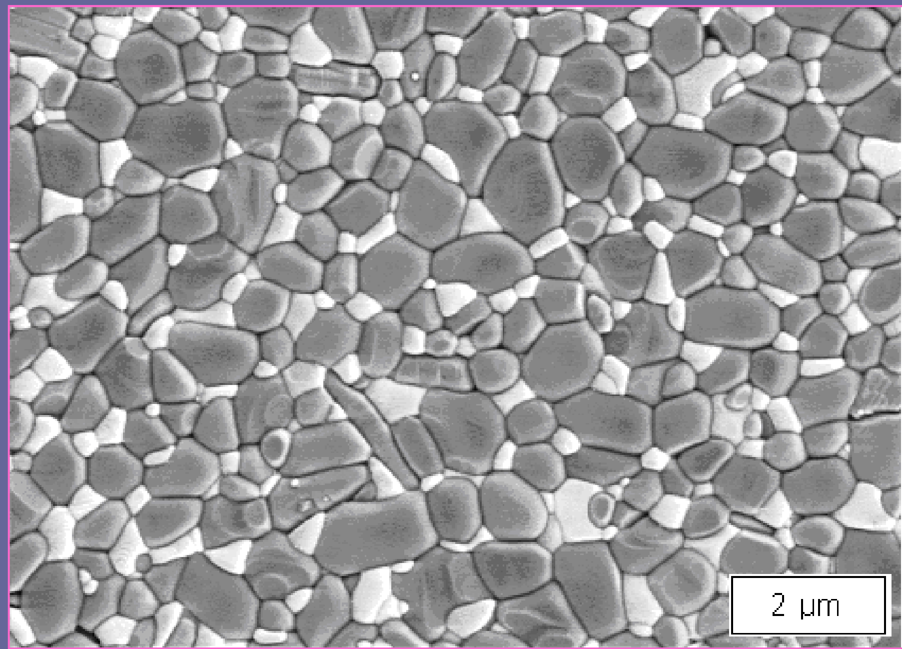
- $Al_2O_3+Cr_2O_3$
- Hardness, Stiffness

Dispersed Phase:

- $ZrO_2+Y_2O_3$
- Toughness, Strength

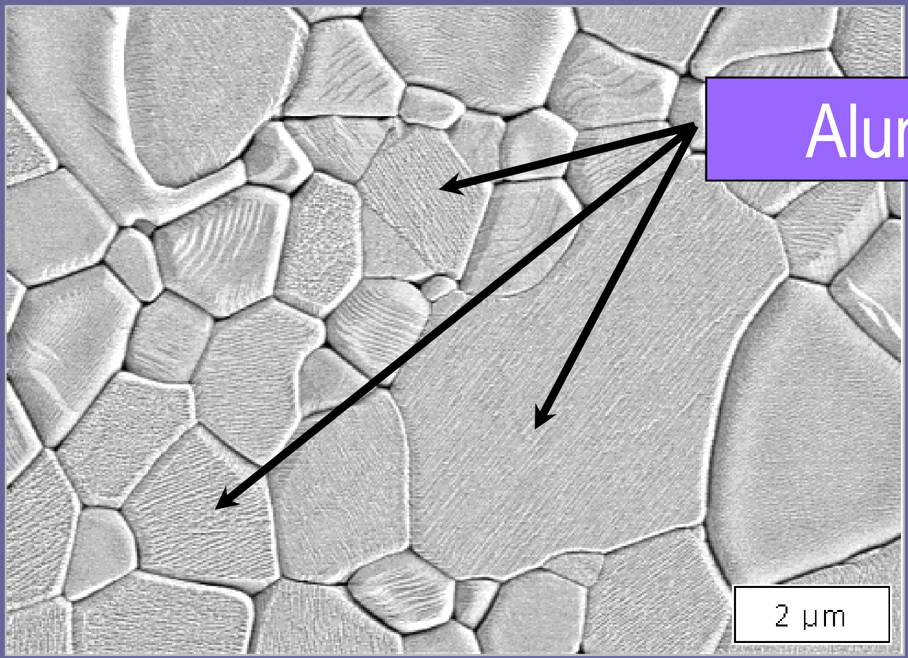
Platelets:

- $SrAl_{12-x}Cr_xO_{19}$
- Toughness, Strength

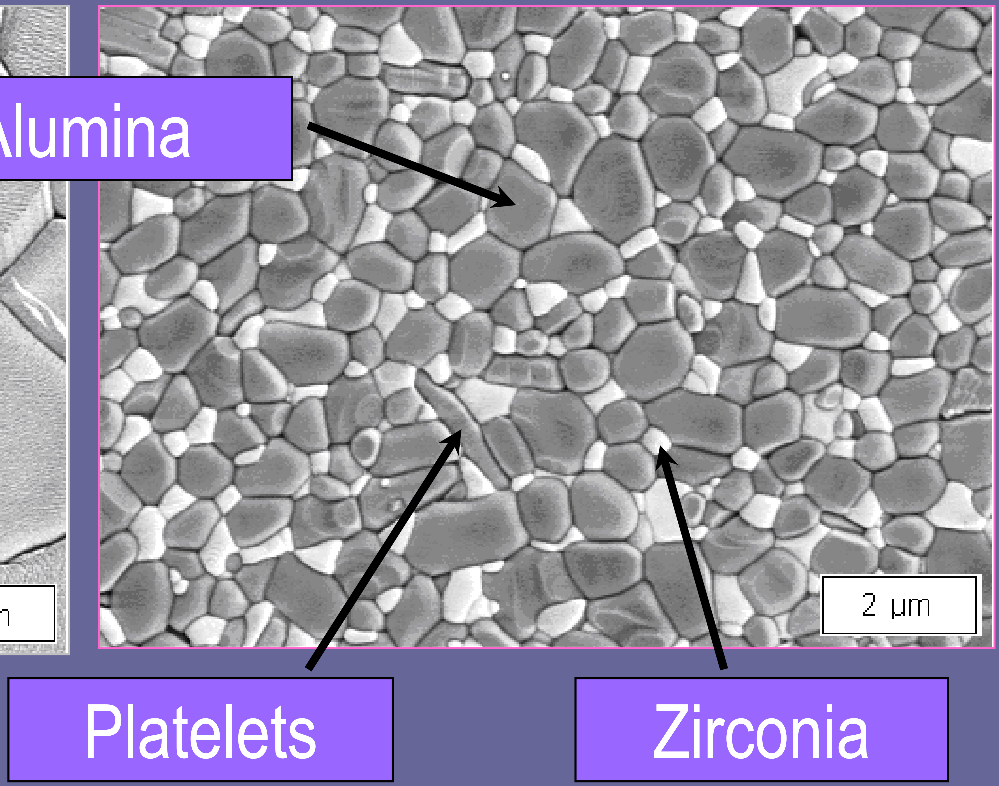


Microstrutture comparison

BIOLOX®*forte*



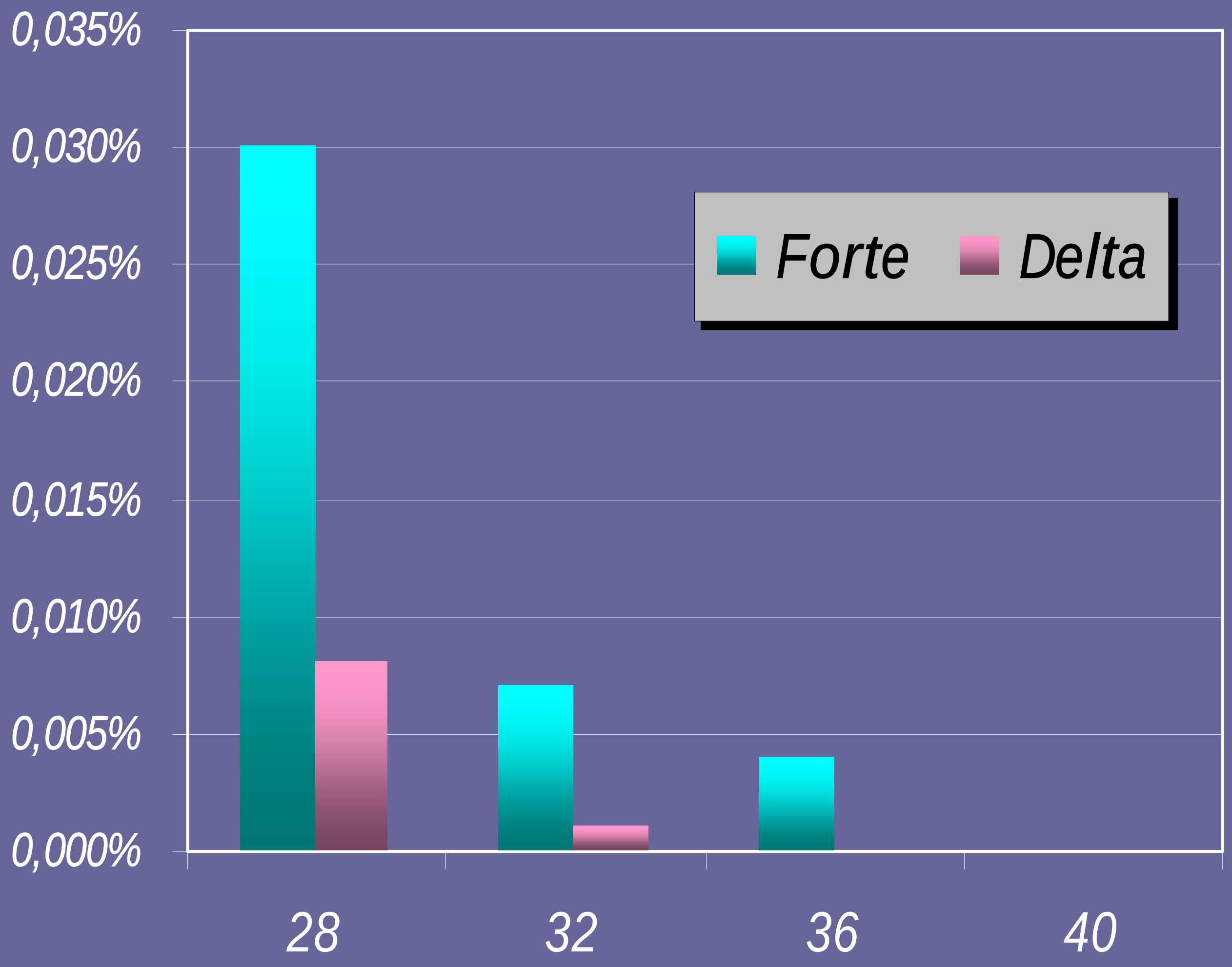
BIOLOX®*delta*



Fracture Strength and Toughness

	Unit	BIOLOX® (since 1974)	BIOLOX® *forte* (since 1995)	BIOLOX® *delta*
Al_2O_3	Vol-%	99,7	>99,8	81,6
ZrO_2	Vol-%	n.a.	n.a.	17
Other Oxides	Vol-%	n.a.	n.a.	1,4
Density	g/cm^3	3,95	3,97	4,37
Grain size Al_2O_3	µm	4	1,750	0,560
4-Pt. Bending strength	**MPa**	**500**	**631**	**1384**
Young's modulus	GPa	410	407	358
Fracture toughness K_{IC}	**MPa $\sqrt{m}$**	**3,0**	**3,2**	**6,5**

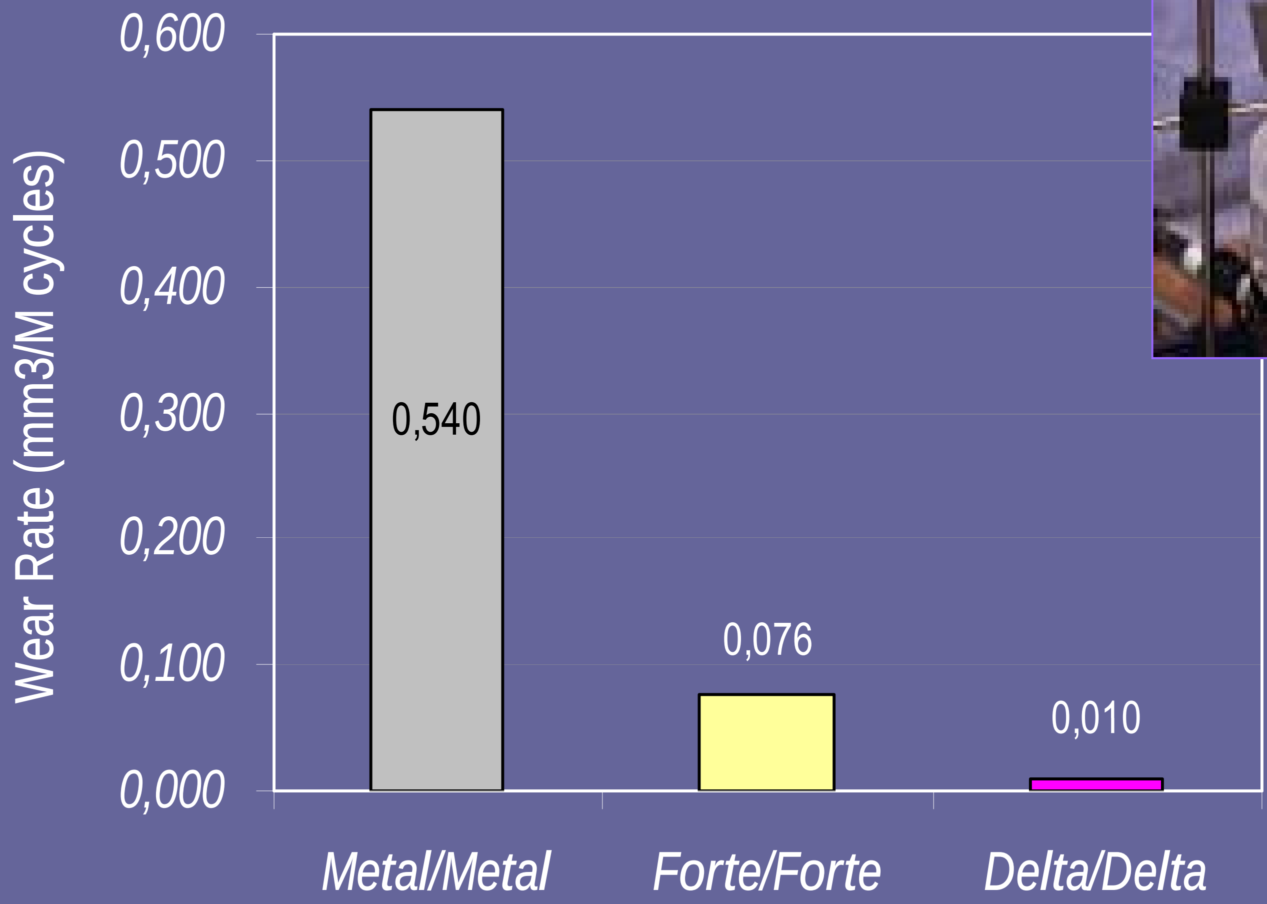
Ball Heads Reliability
BIOLOX®forte Vs. delta – Fracture frequency



(dati: CeramTec GmbH)

Wear: Hip Simulator, Leeds University

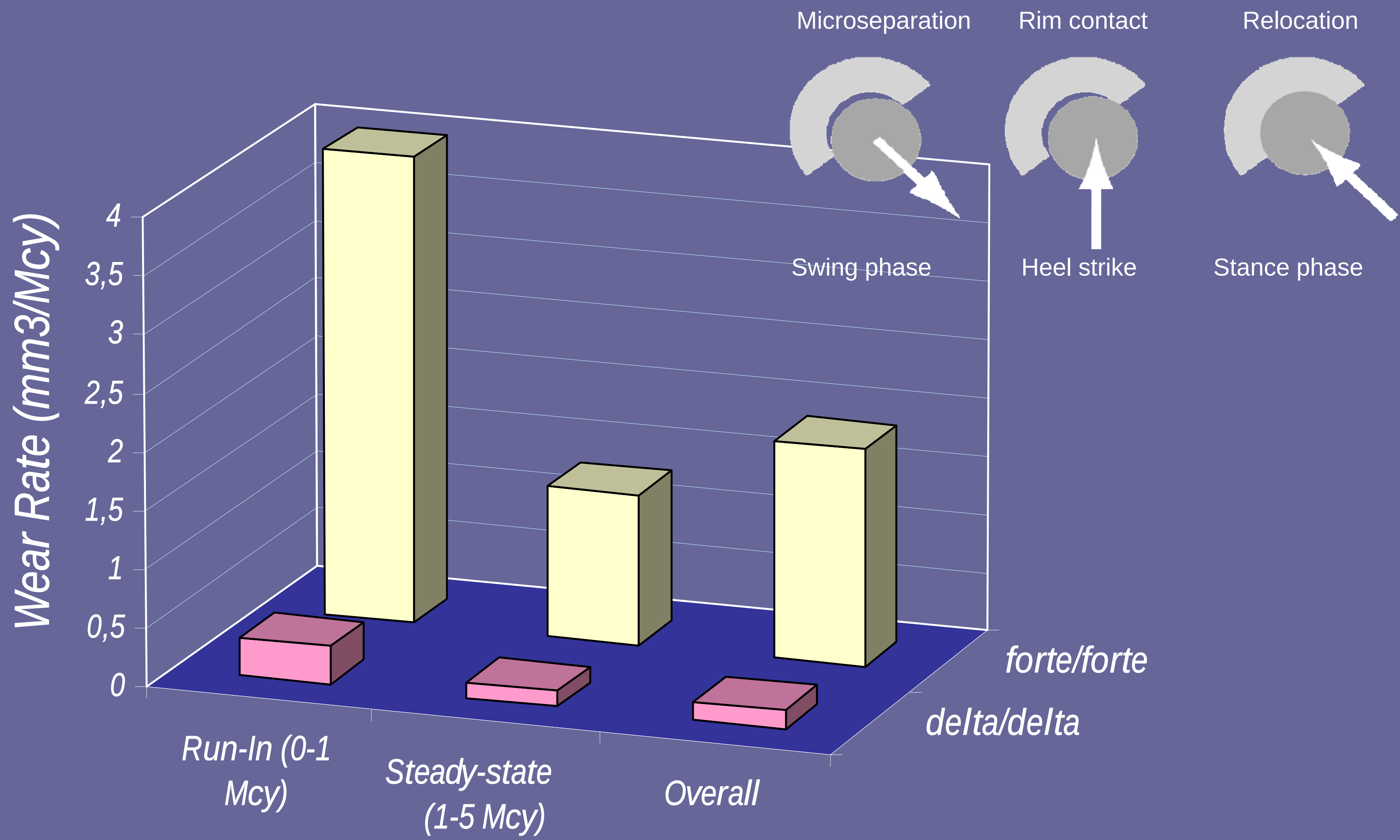
Standard Mode Test



(Dati: Dowson, D et al., 2002)

Wear: Hip Simulator, Leeds University

Microseparation Mode Test



(Dati : Stewart TD, et al., 2003)

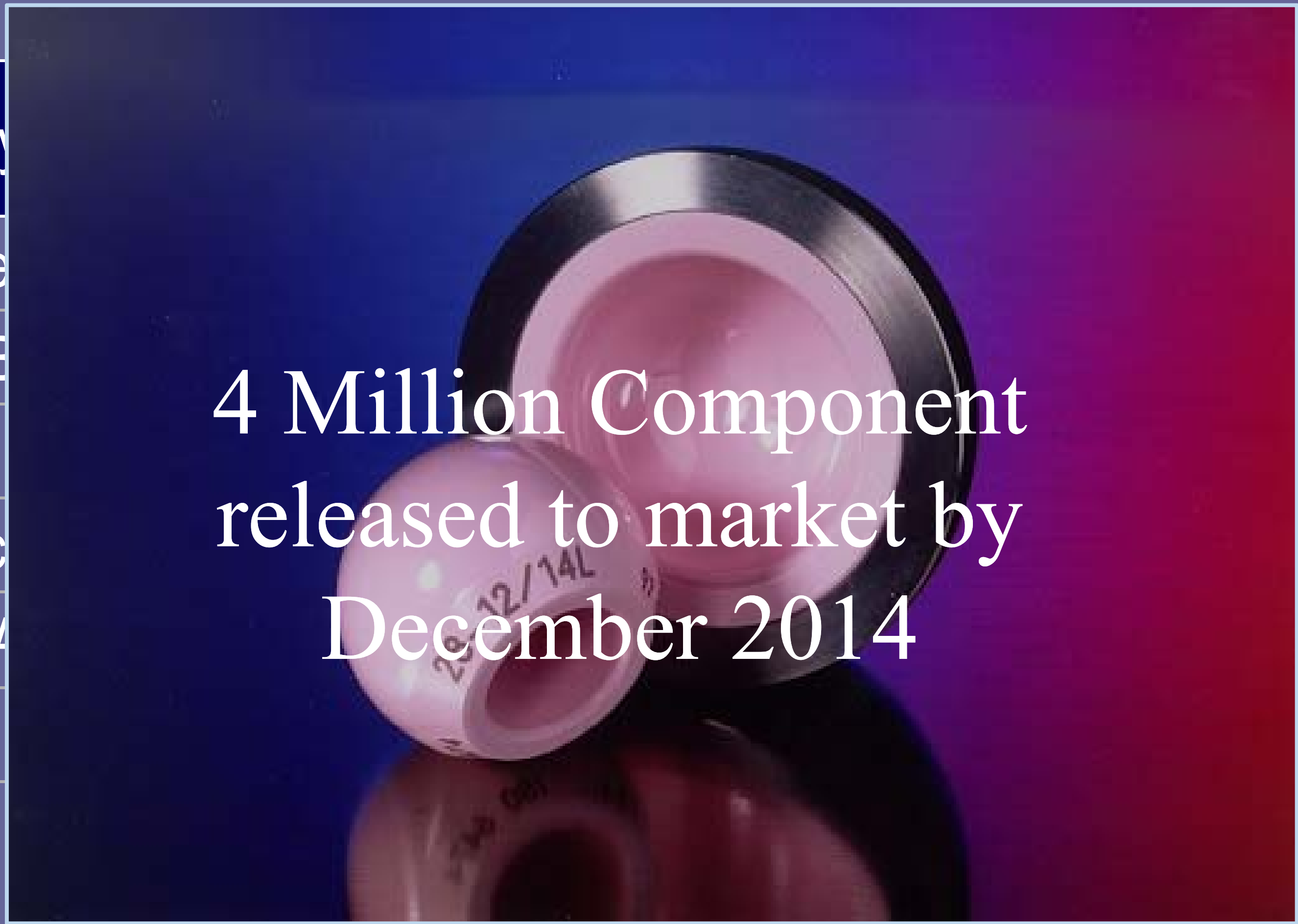
Summary

- The Precursors
- 1970s : The Pioneers
- 1980 – 2004: The Development
  - Alumina
  - Zirconia
  - ZTA – ATZ composites
- Bioceramics in Hip Joint Replacements Today

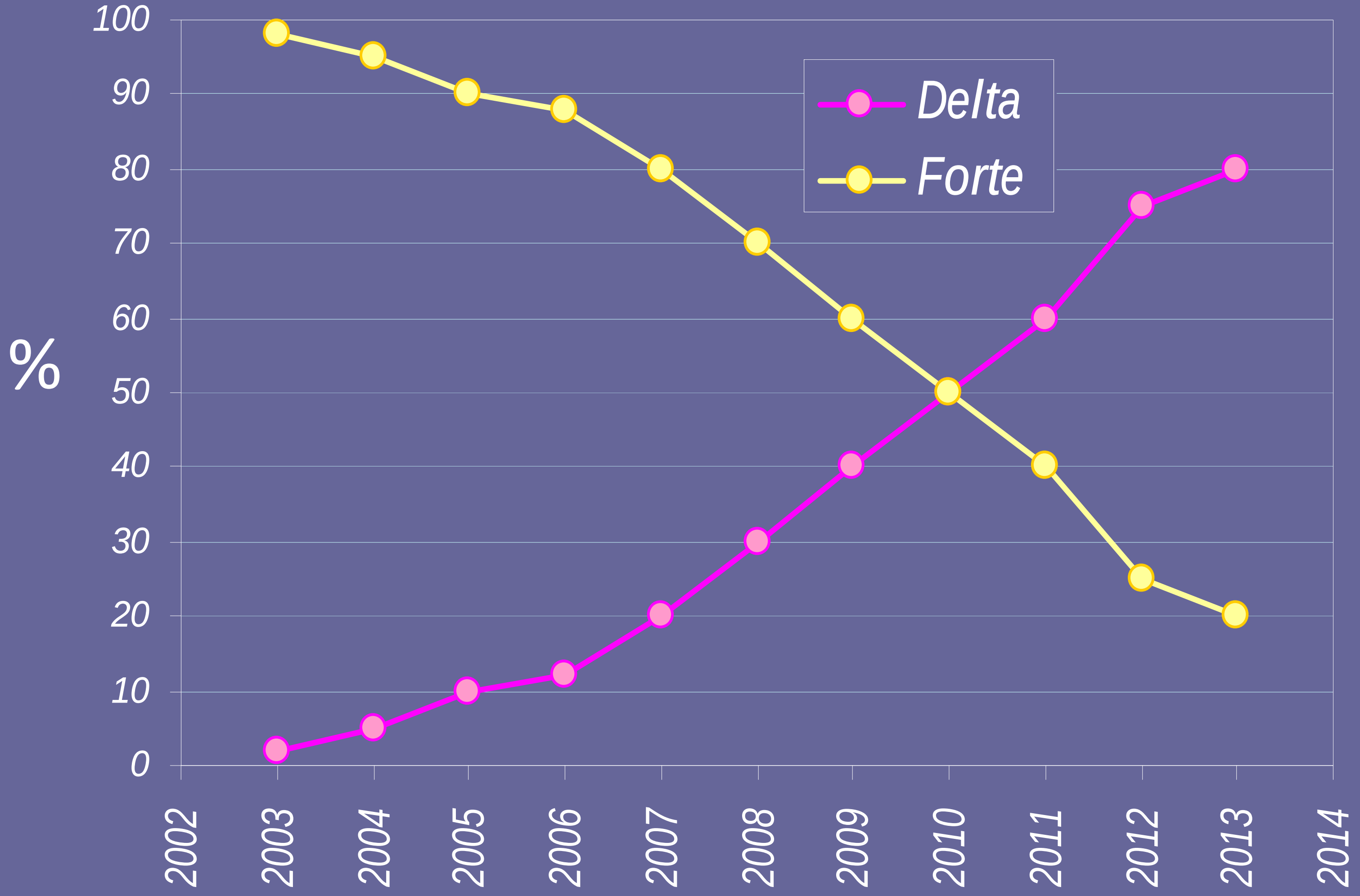
Alumina-Zirconia Composites

THR ball heads

Company	e
CeramTe	*elta*
Mathys E	®
Kyocera	AZUL
C5Medic	
Morgan A	C
Metoxit	o ®



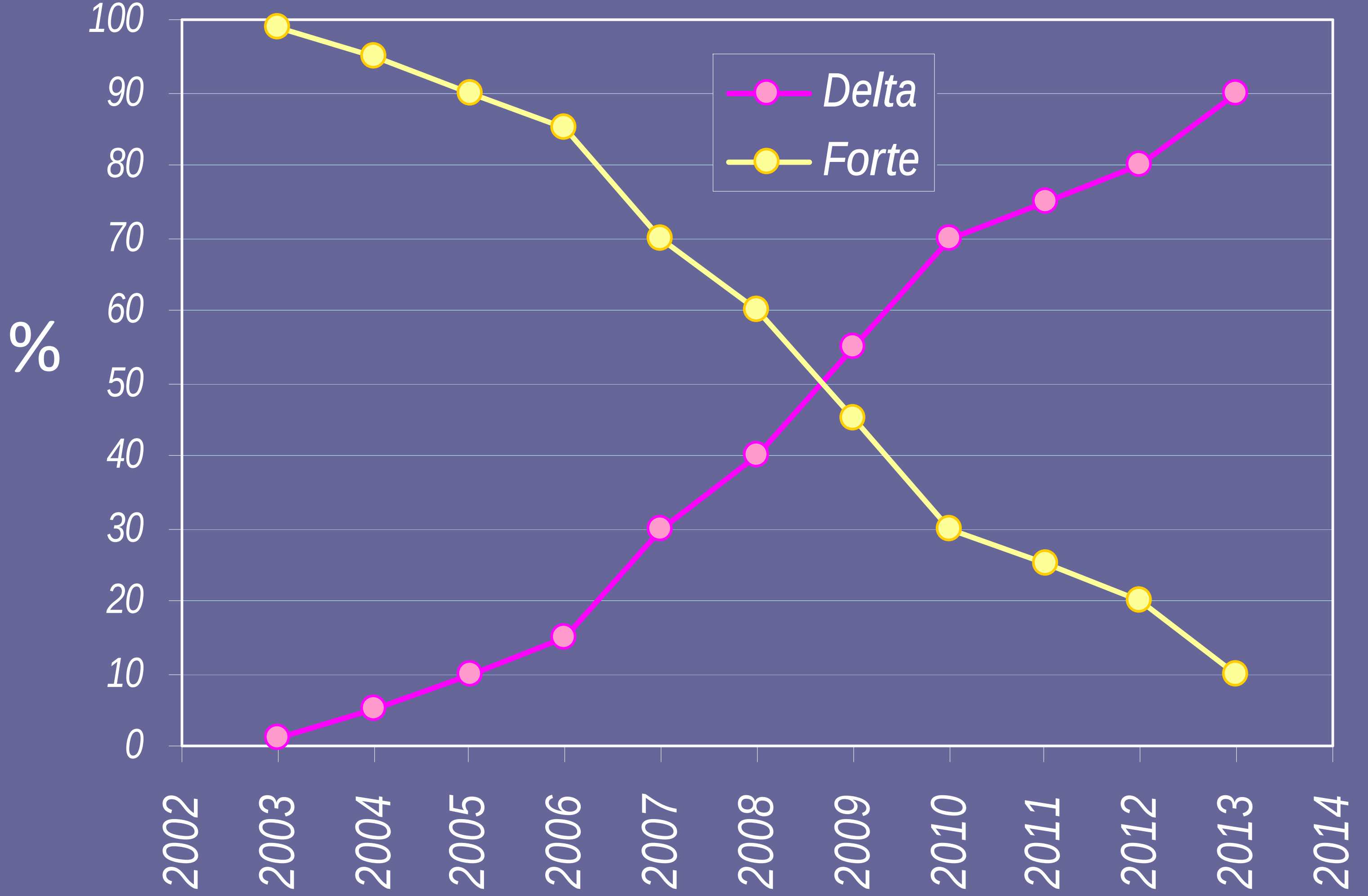
Percent Distribution BIOLOX® forte/delta
THR Heads



(Data: CeramTec GmbH)

Percent Distribution BIOLOX® forte/delta

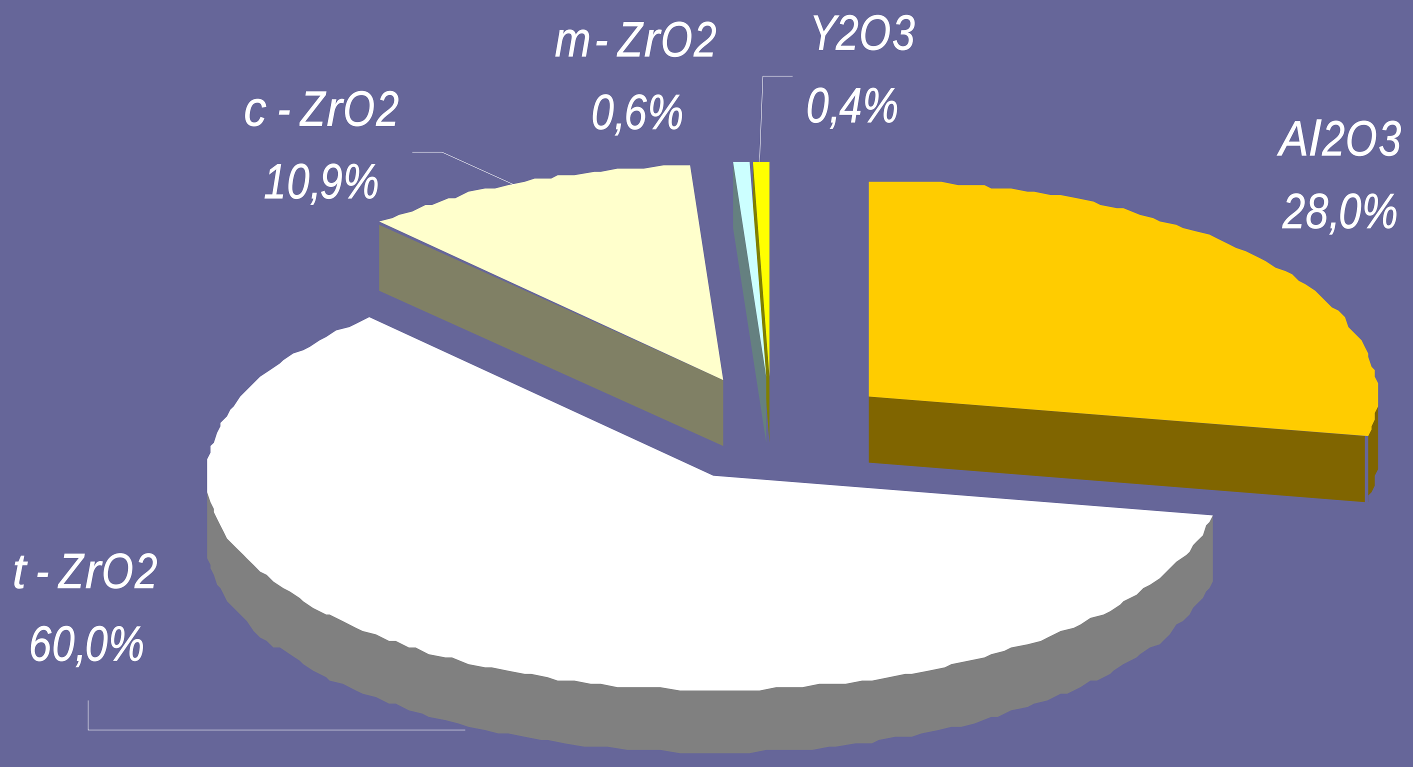
THR Inserts



(Data: CeramTec GmbH)

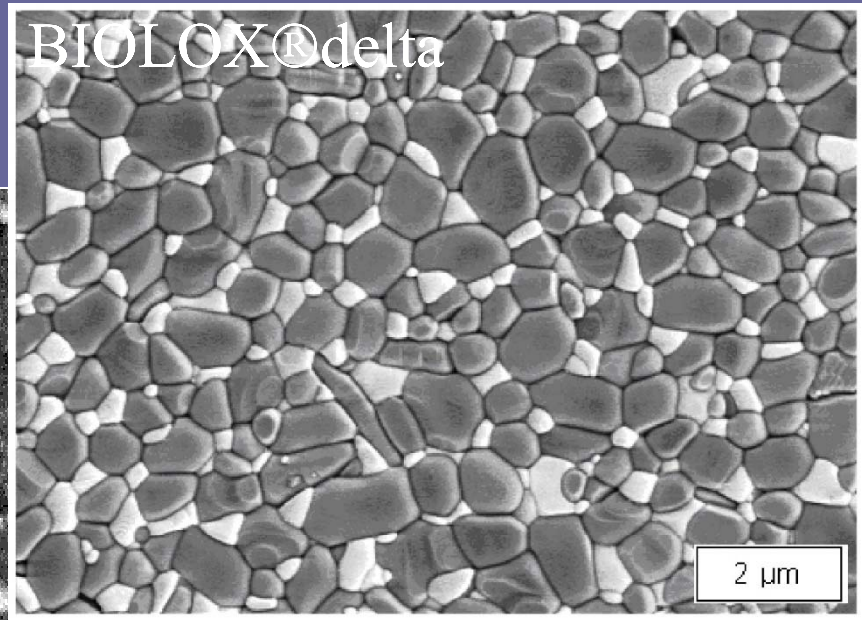
Ceramys® ATZ

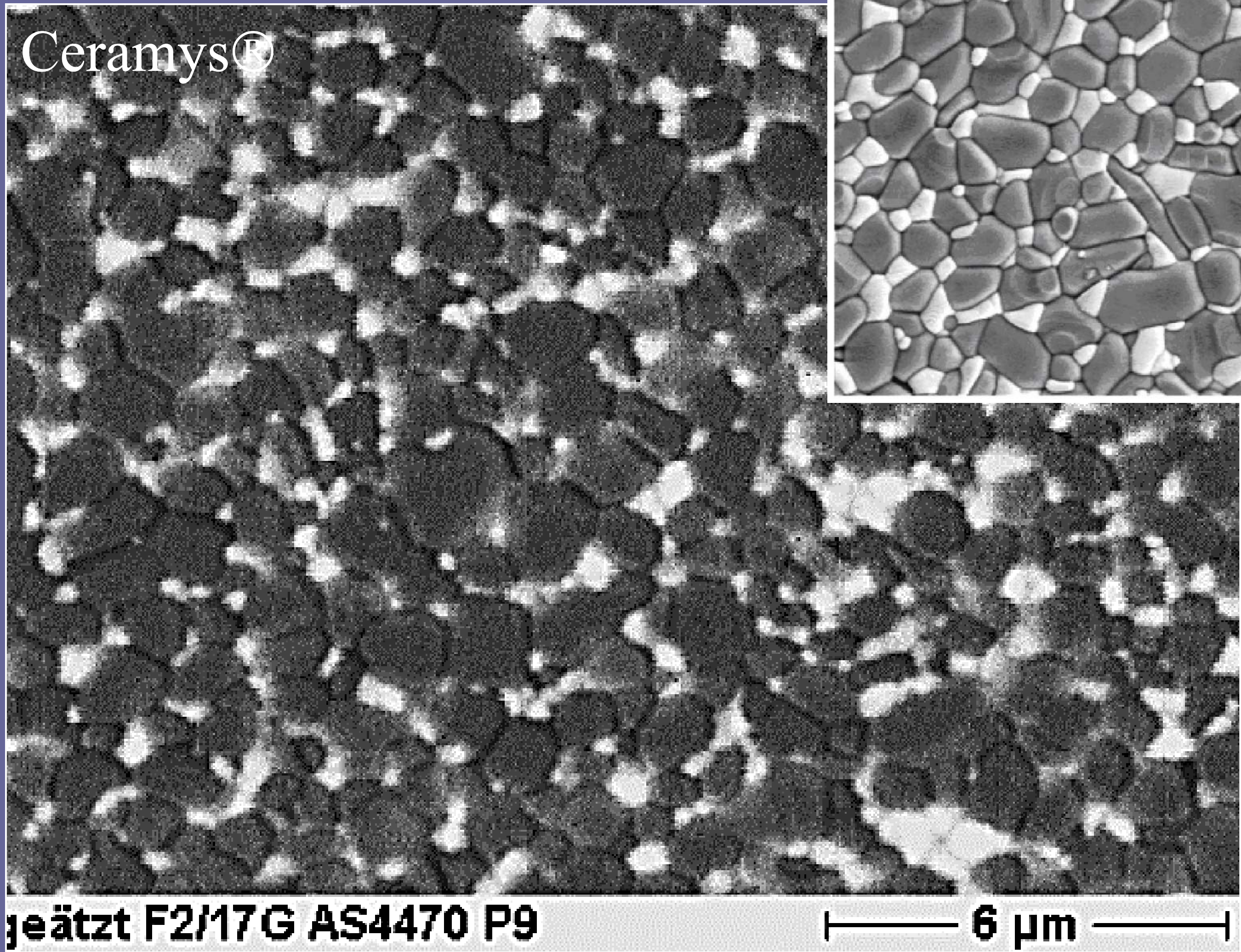
Composition (vol%)



Ceramys® ATZ

Microstructure



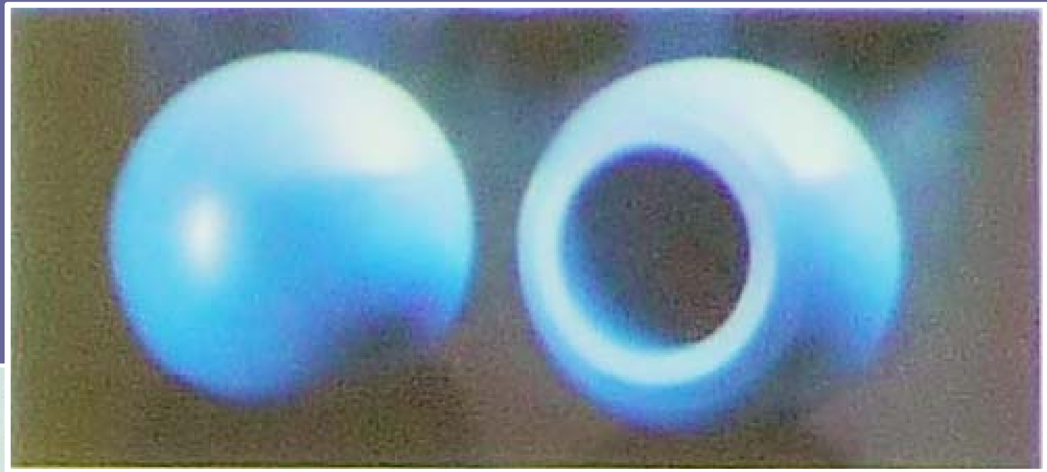


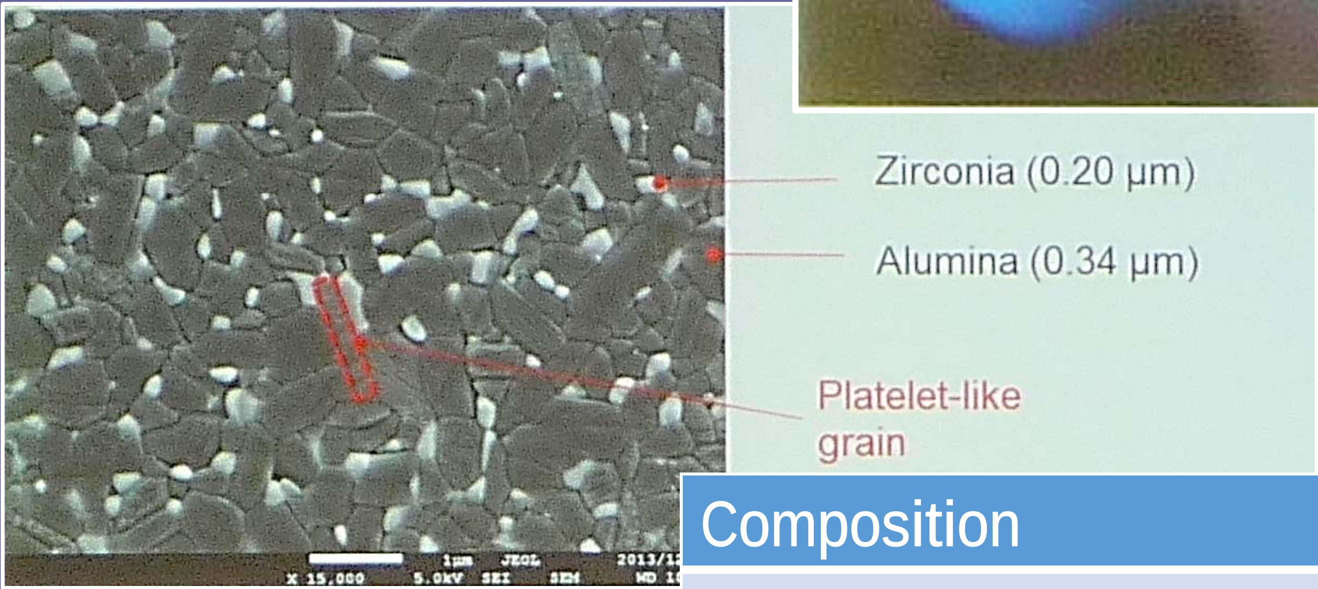
Ceramys® ATZ Vs. BIOLOX®delta

Proprietà	***Unità***	***BIOLOX delta***	***Ceramys***
Composizione	%wt	Allumina 75 Zirconia 24 Other 1	Allumina 20 Zirconia (m+t) 80
Resistenza a Flessione	MPa	1384	1250
Weibull modulus	--	13	--
Toughness K_{IC}	MPam½	6,5	7,4
Young modulus	GPa	350	--
Durezza	HV	1975	--
Thermal Cond.	W/mK	16,7	5,8

BIOCERAM® AZUL ZPTA

(J. Ikeda, et al., 2014)

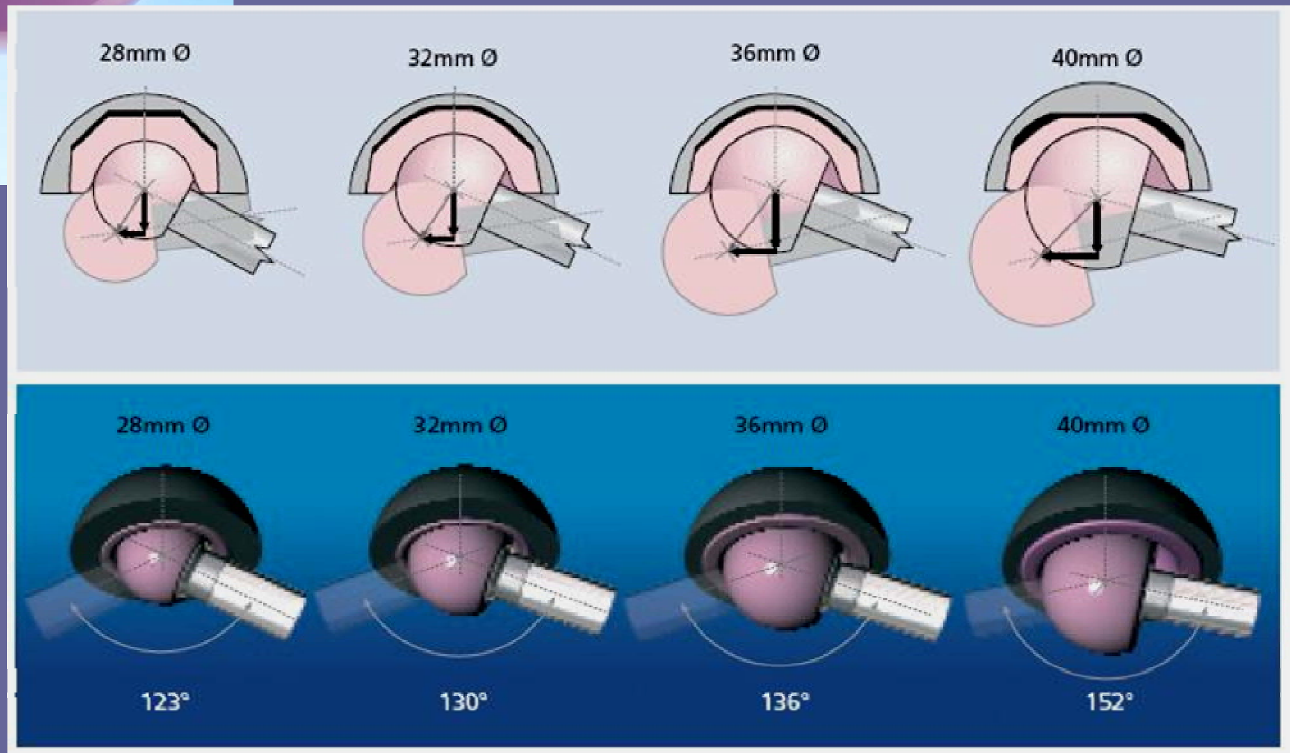




Composition	wt%
Alumina	77 - 82
Zirconia	16,5 - 20
Additives (Si, Ti, Mg, Co)	1,7 – 3,4

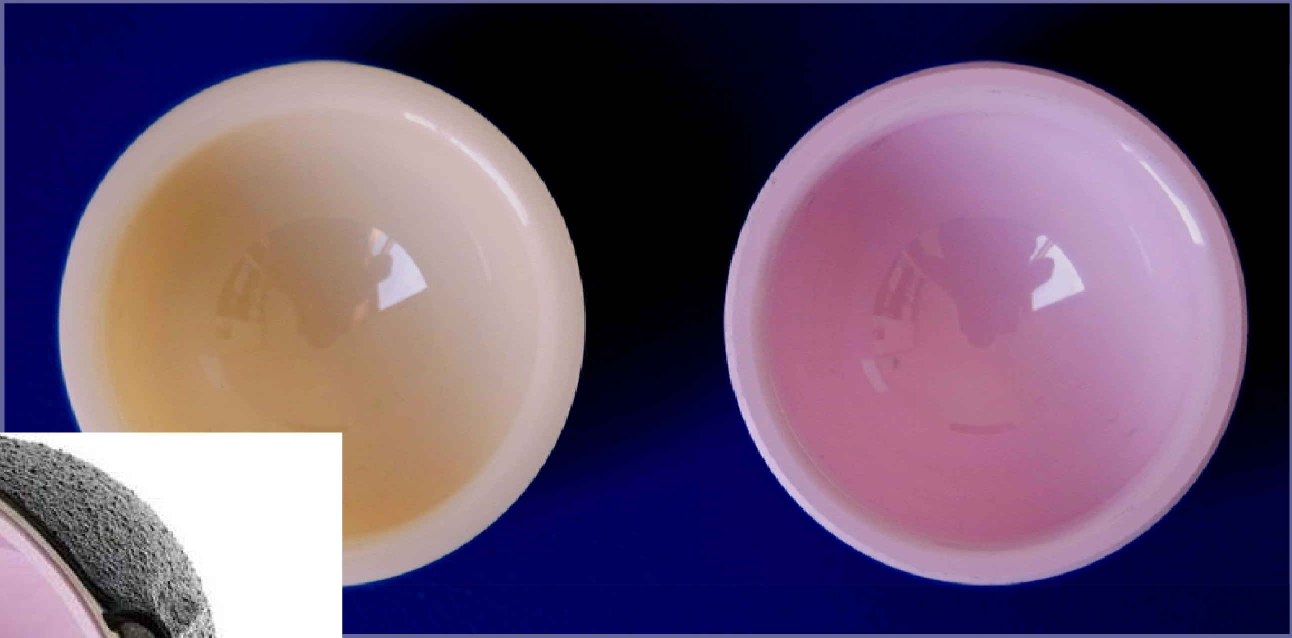
BIOLOX®delta: New Devices

Large Diameter Bearings



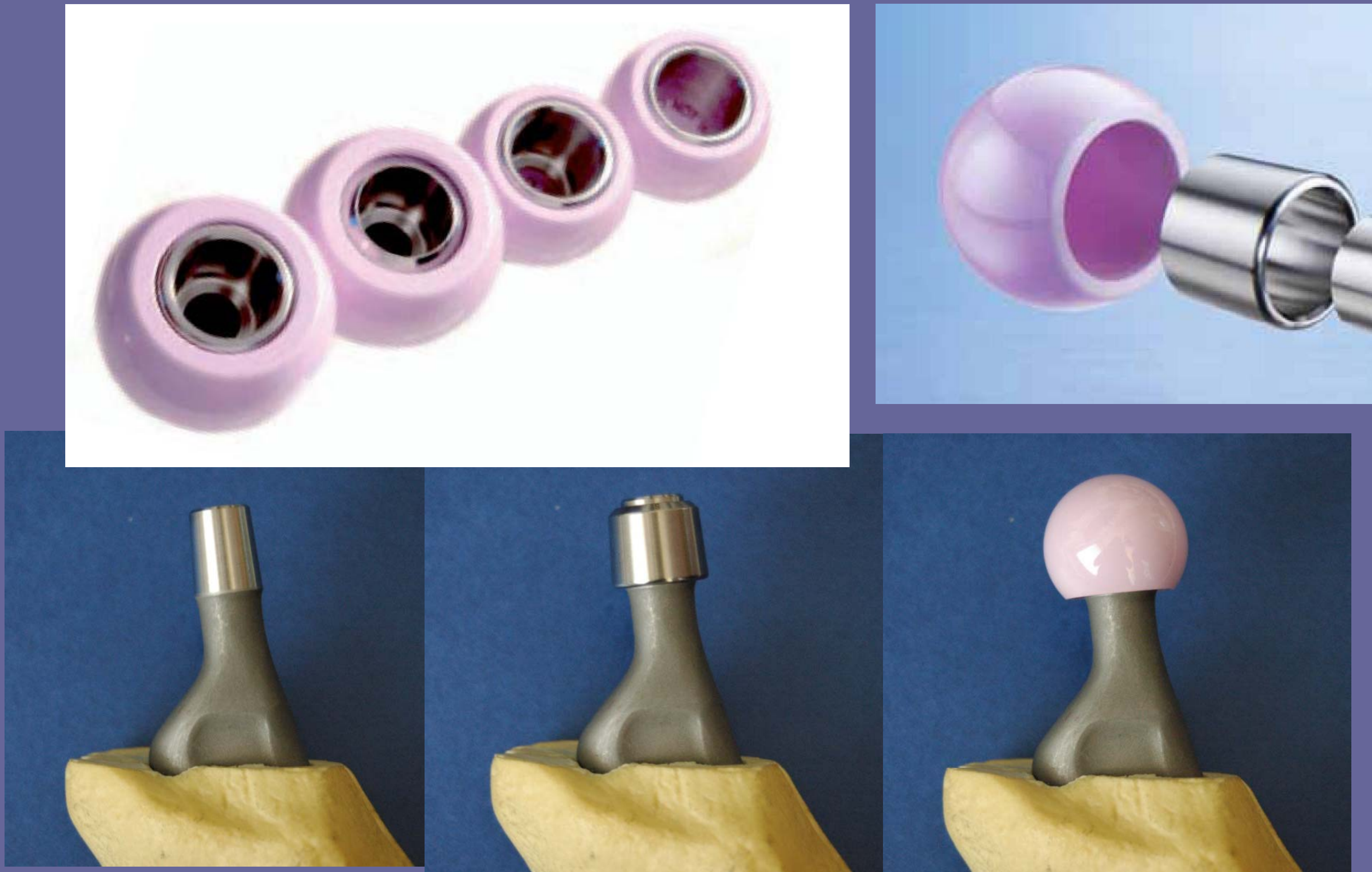
BIOLOX®delta: New Devices

Thinner Ceramic Inserts, Monoblock Cups



BIOLOX®delta: New Devices

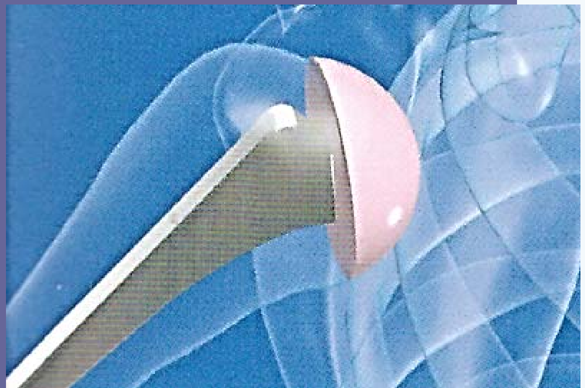
Revision Ceramic Ball Heads



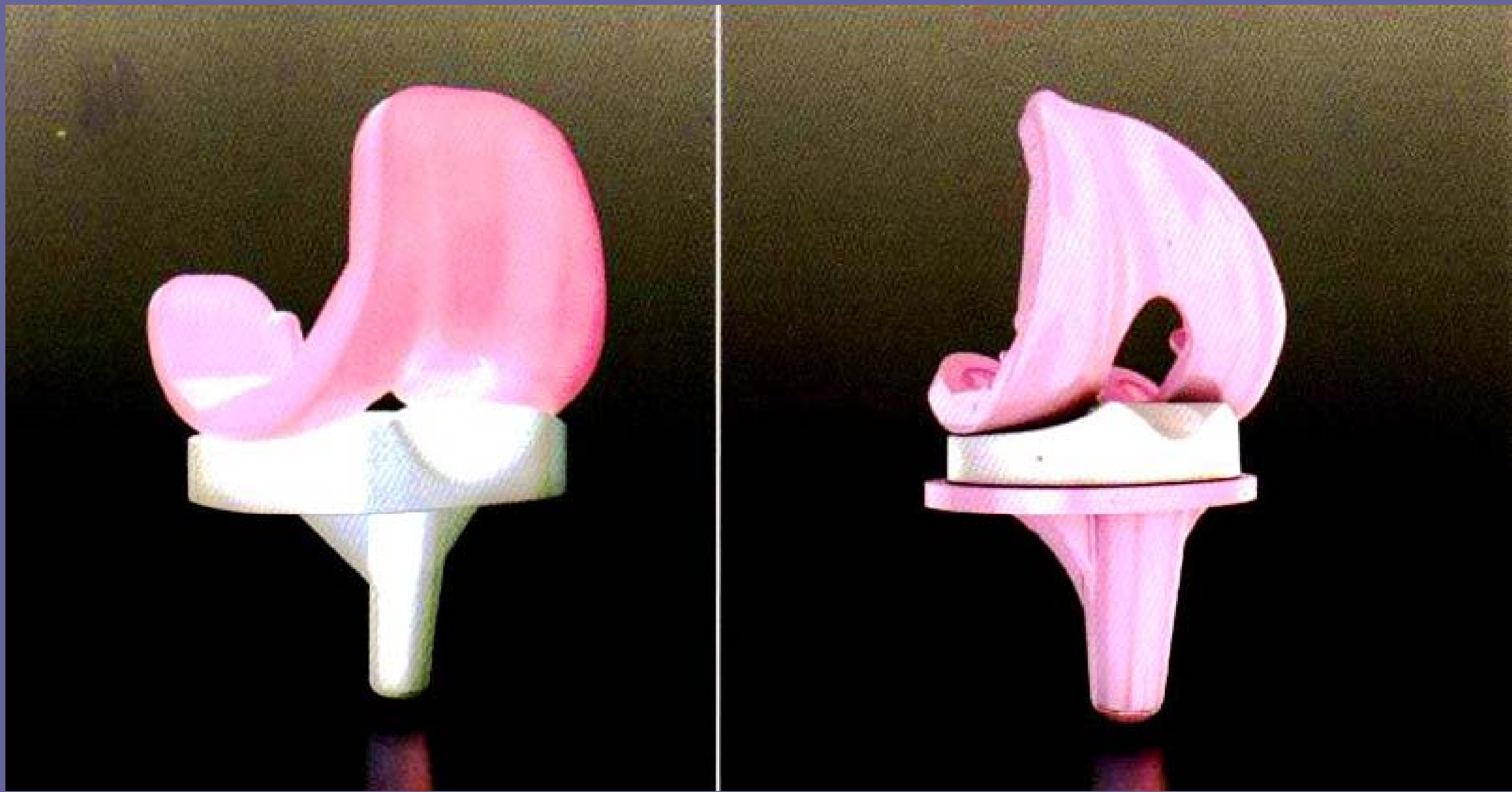
BIOLOX®delta: New Devices
Tri-polar & Resurfacing Hip Replacements

BIOLOX®delta: New Devices

Shoulder /Ankle/Elbow/Hand /Skull



BIOLOX®delta: New Devices
Knee Replacements



Other Ceramics in THR Ball Heads

- Bulk Ceramics
  - Silicon Nitride (Si3N4)

- «Ceramized» Surfaces
  - Titanium Nitride (TiN)
  - Zirconium Nitride (ZrN)
  - Diamon-Like Carbon (DLC)
  - Zirconium Dioxide (m-ZrO2)

NOx Ceramics in THRs:

Silicon Nitride Si_3N_4

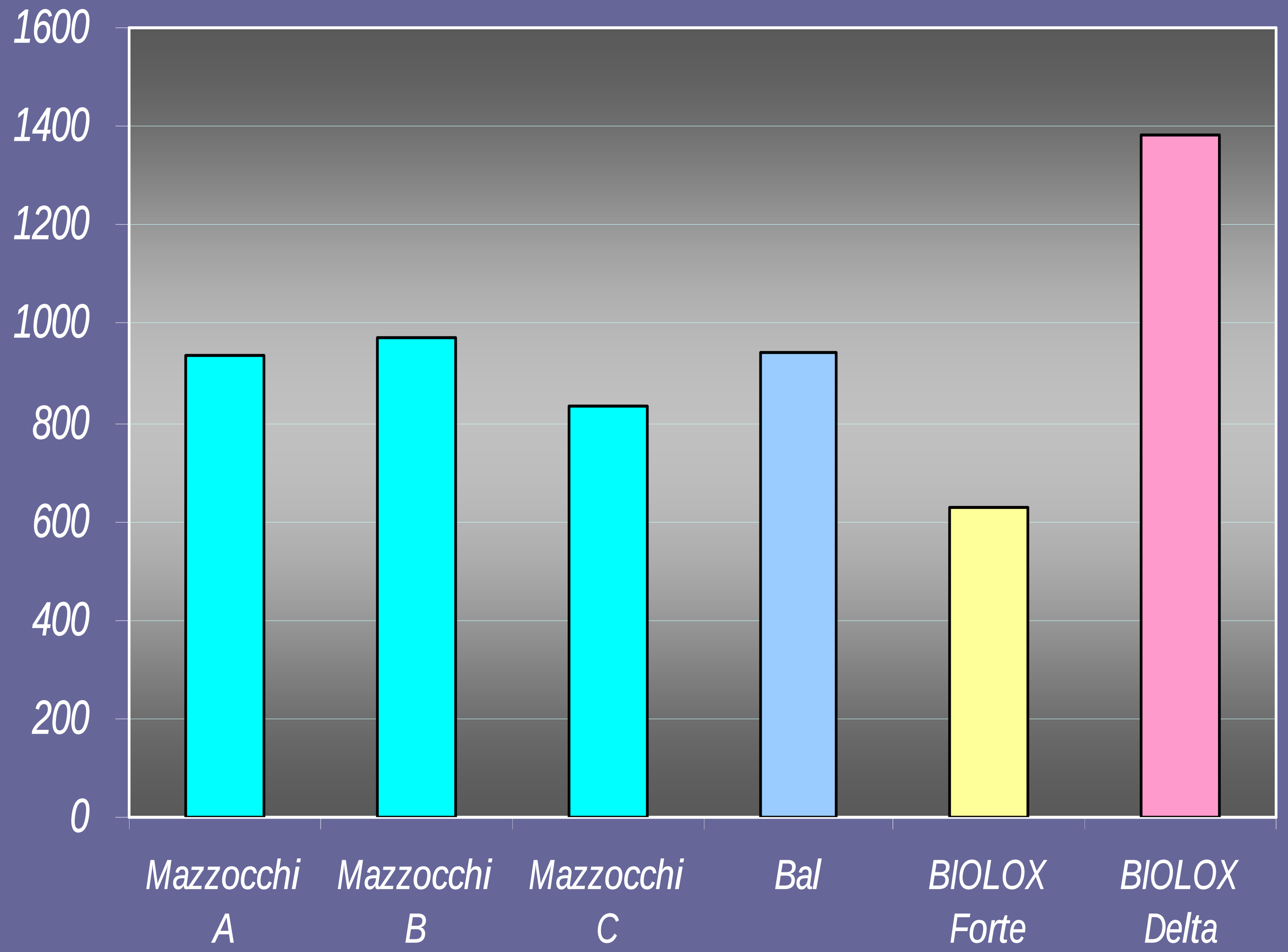
Today:

- Spinal cages
- Miniplates for MF surgery

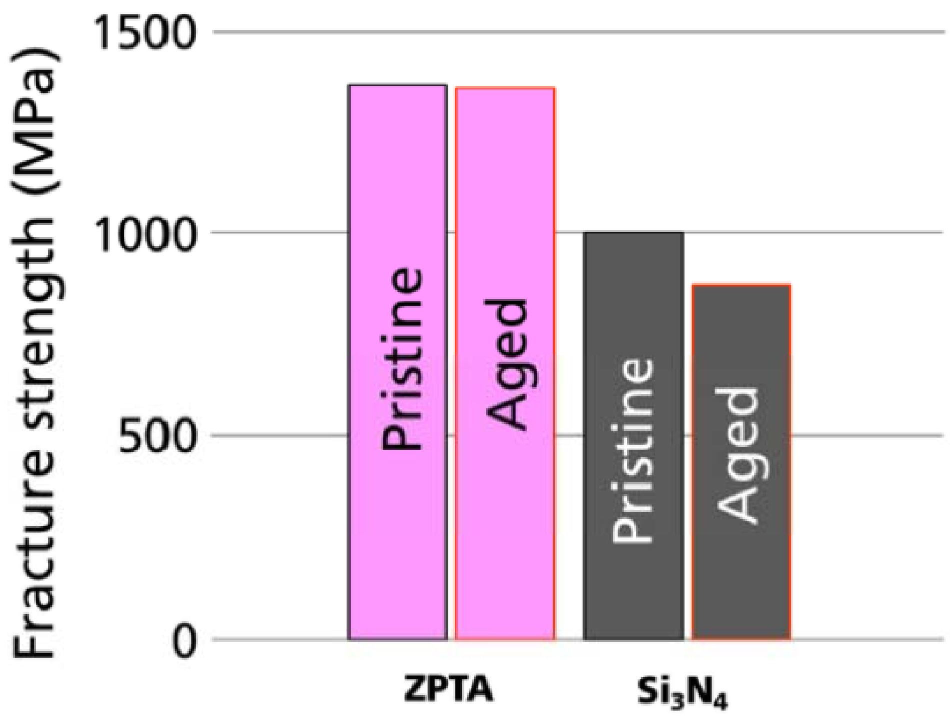
Tomorrow:

- Dental Implants (?)
- Aneurism clips (?)
- THR ball heads & inlays (?)

NOx Ceramics in THRs:
Silicon Nitride Si_3N_4: Bending Strength



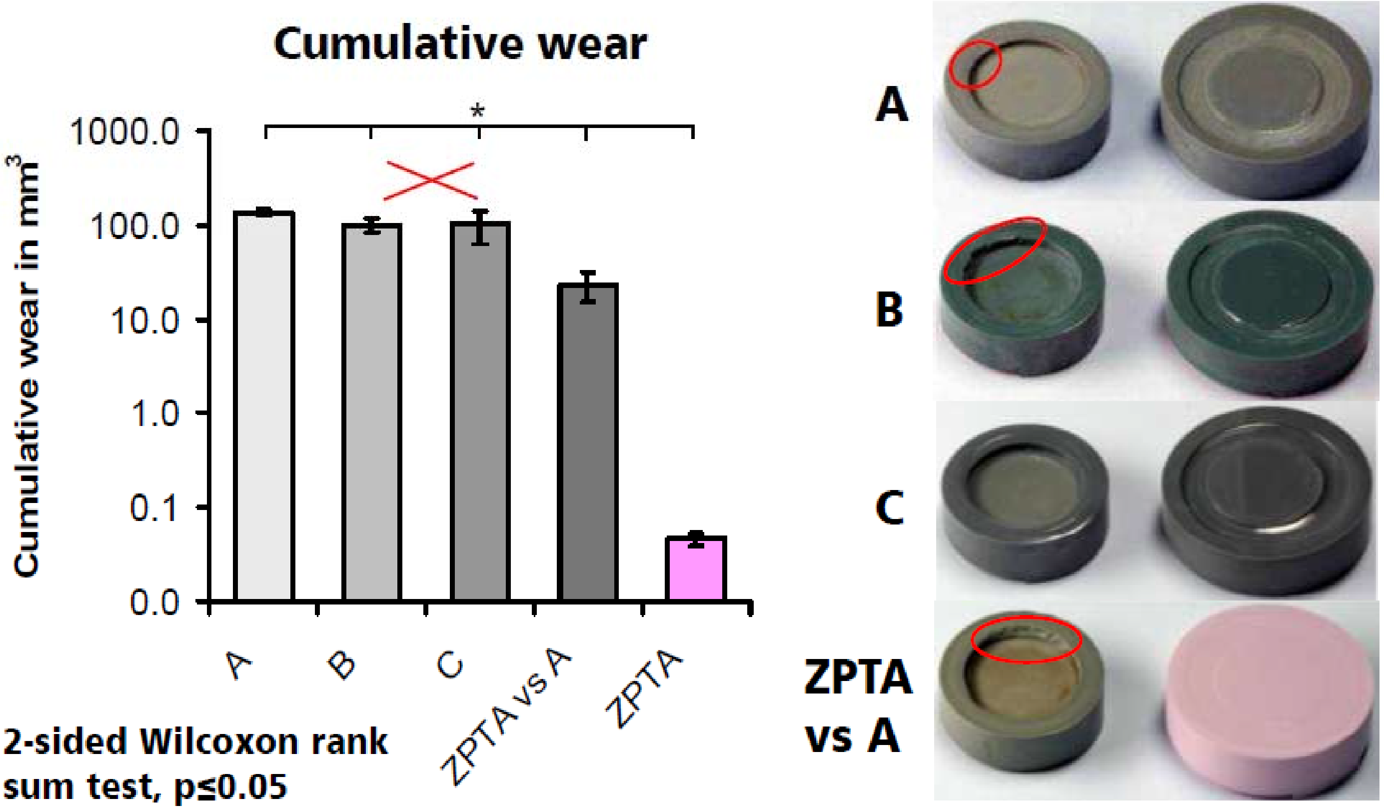
NOx Ceramics in THRs:
Silicon Nitride Si_3N_4 : Ageing



Ageing in autoclave at 134°C, 2 bar and 10h (ISO 6774-2)

(A. Porporati, ISTA 2014)

NOx Ceramics in THRs:
Silicon Nitride Si_3N_4 : Wear



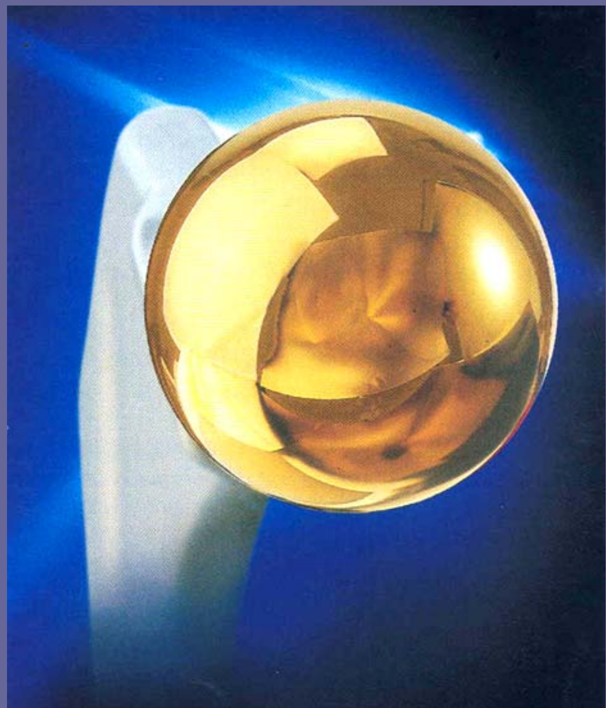
	A	B	C	ZPTA vs A	ZPTA
Final torque (Nm)	9.0±0.7	9.2±0.5	9.5±0.5	7.7±1.6	5.2±1.1

(A. Porporati, ISTA 2014)

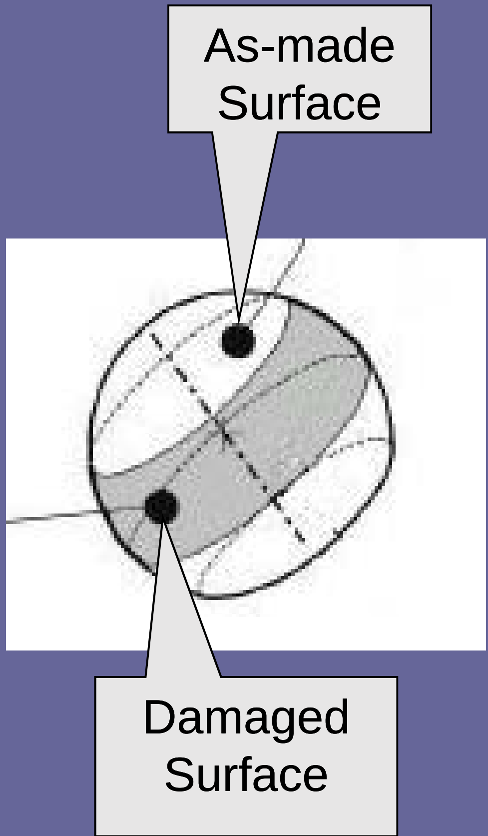
NOx Ceramics in THRs:
Titanium Nitride (TiN) Coatings

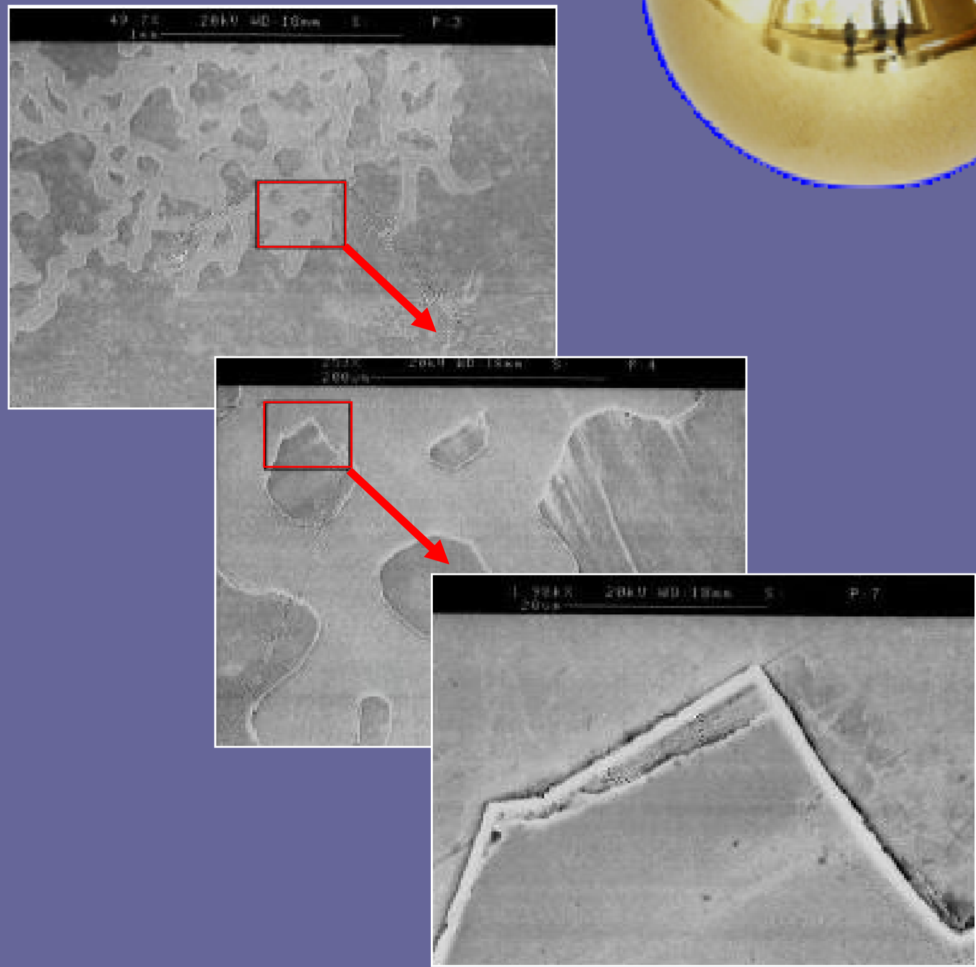
Development started on the early eighties

Used in hip, knee, ankle replacements
and in ostosintesis devices
(plates, screws)



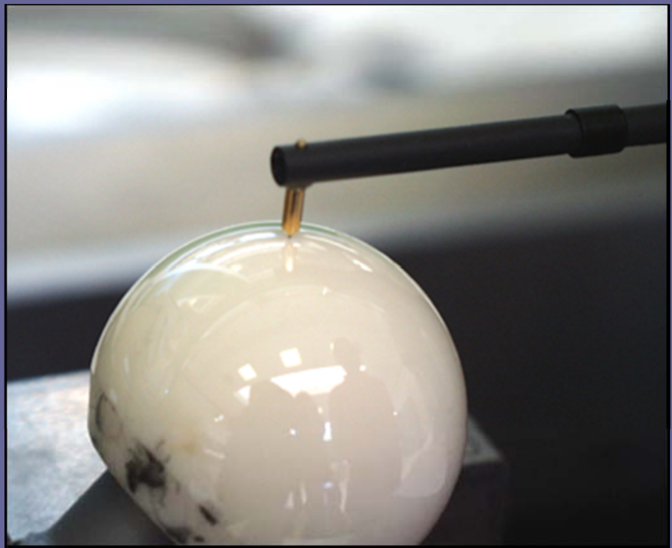
NOx Ceramics in THRs:
Titanium Nitride (TiN) Coatings

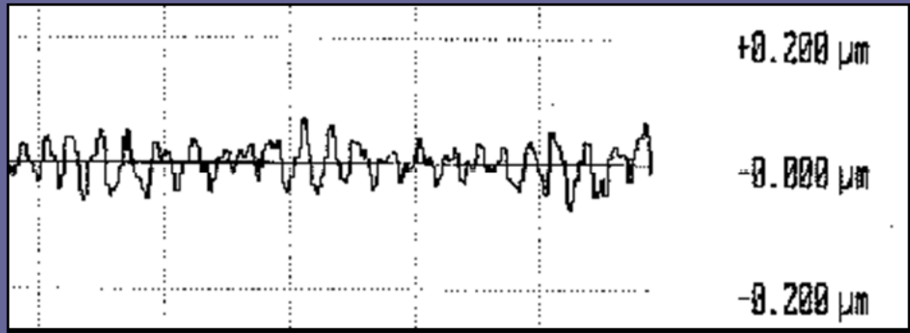


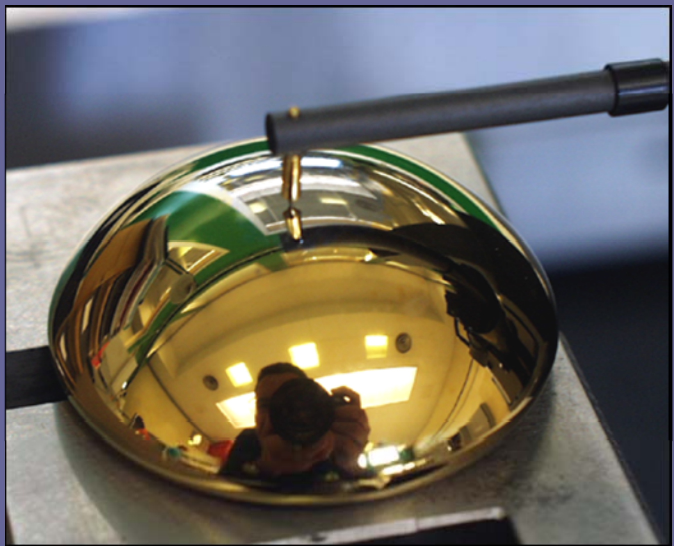


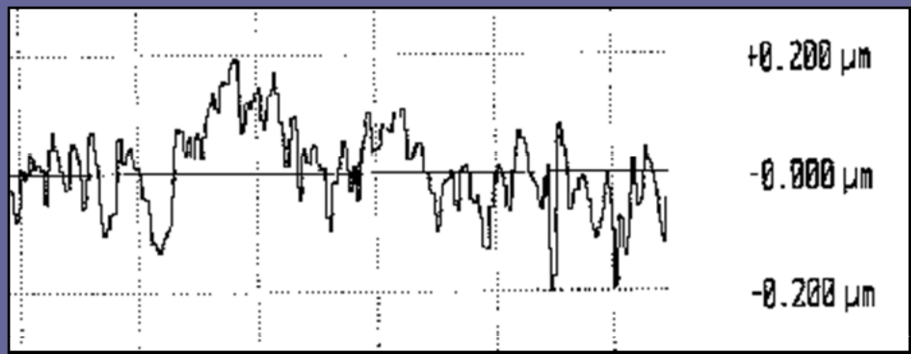
(Da:Raimondi MT, Pietrabissa R , 2000)

NOx Ceramics in THRs:
Titanium Nitride (TiN) Coatings









Nox Ceramics in THRs:
Zirconium Nitride (ZrN) Coatings

NOx Ceramics in THRs:
Diamond-Like Carbon (DLC)

Diamond-Like Carbon is an amorphous diamond containing mixed sp^2/sp^3 bonds.

The process must control the diamond/graphite ratio (sp2/sp3) and the residual stresses (leading to coating spallation)

NOx Ceramics in THRs:

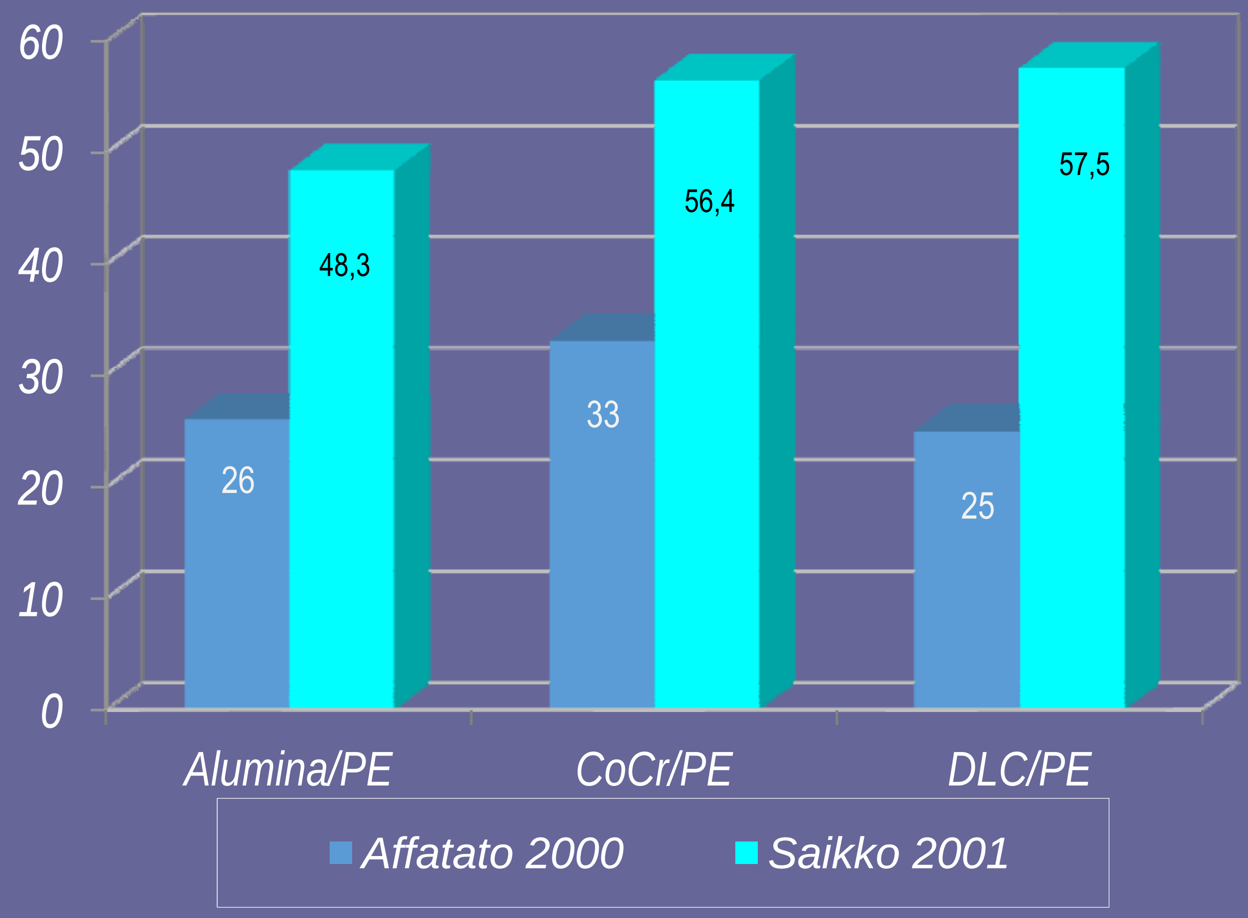
Diamond-Like Carbon (DLC)

Property	Unit	Diamond	DLC
Hardness	Kg/mm^2	7000-10000	1200-3000
Coeff. Friction (air)	--	0,1	0,7
Lattice constant	nm	35,67	Amorphous
Thickness	µm	--	1 - 2
Density	g/cm^3	3,51	1,6 - 2,2
Bonding	--	Covalent sp^3	Mixed sp^2 sp^3

(Franks J, et al. Met Mater 1991;
Monaghan DP et al. Mater Wold 1993)

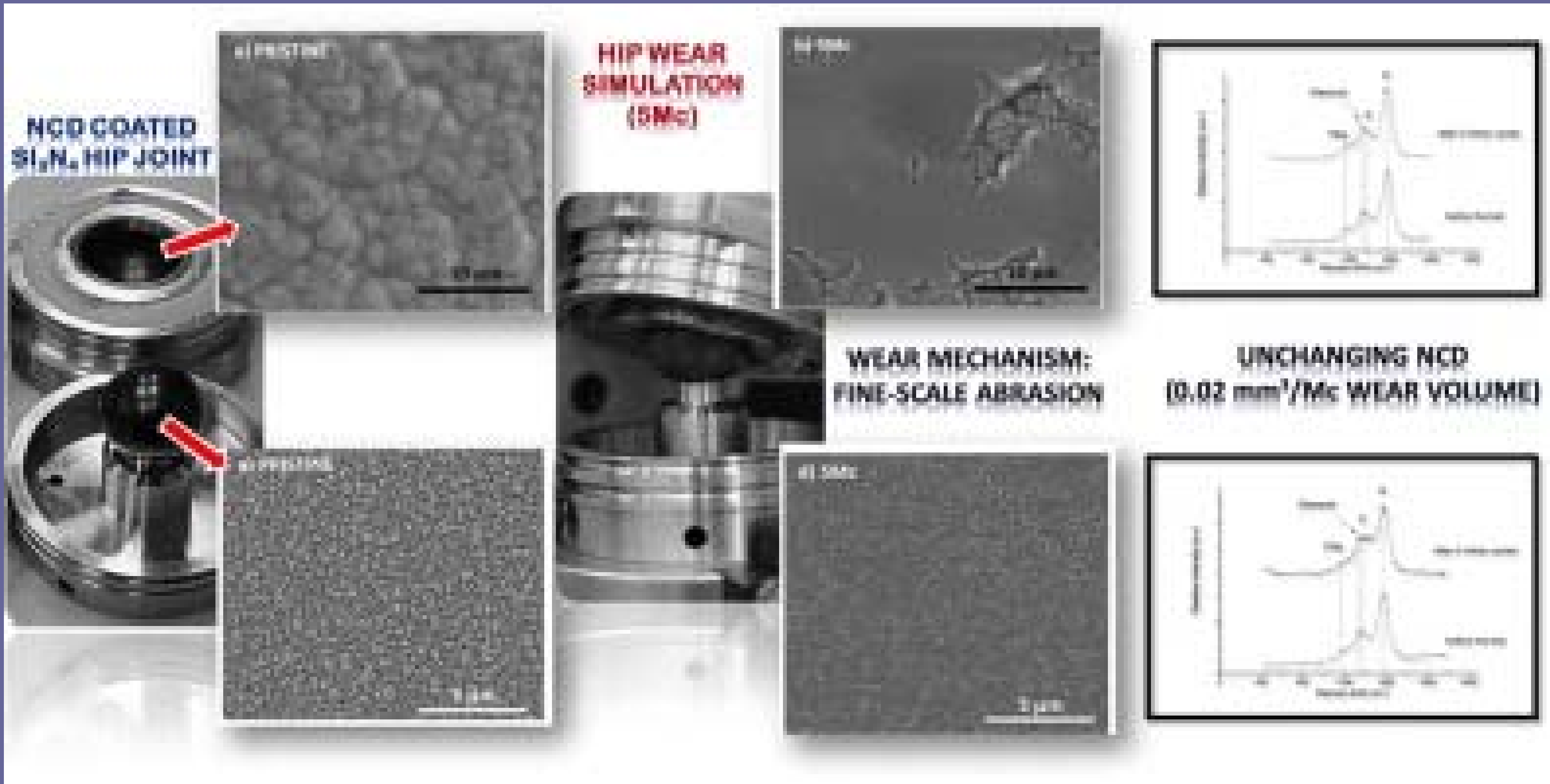
NOx Ceramics in THRs:
Diamond-Like Carbon (DLC) - Wear

PE Weight Loss
($mg/10^6$ Cycles)
Hip Simulator



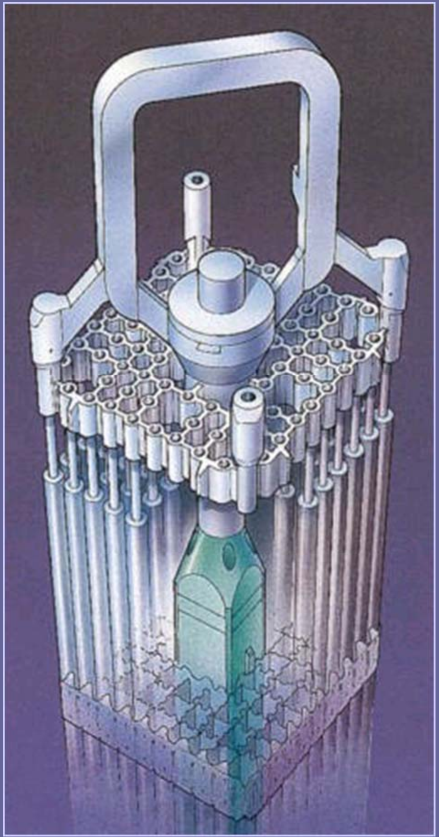
(Affatato S, et al., 2000; Saikko V, et al., 2001)

NOx Ceramics in THRs:
CVD Diamond (Maru, et al., 2015)



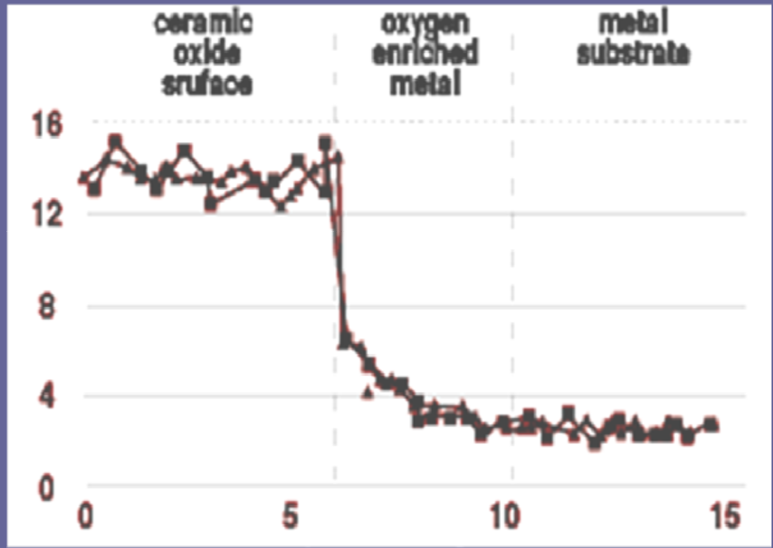
Ceramized Surfaces in THRs:

Oxidized Zr- 2,5Nb Alloy – OXZr (Oxinium®)



Technology used in LWR to prevent Zirconium Hidrides formation on fuel cladding.

m- ZrO_2 layer formation by oxidation (3h, 538°C) of Zr-2,5%Nb alloy

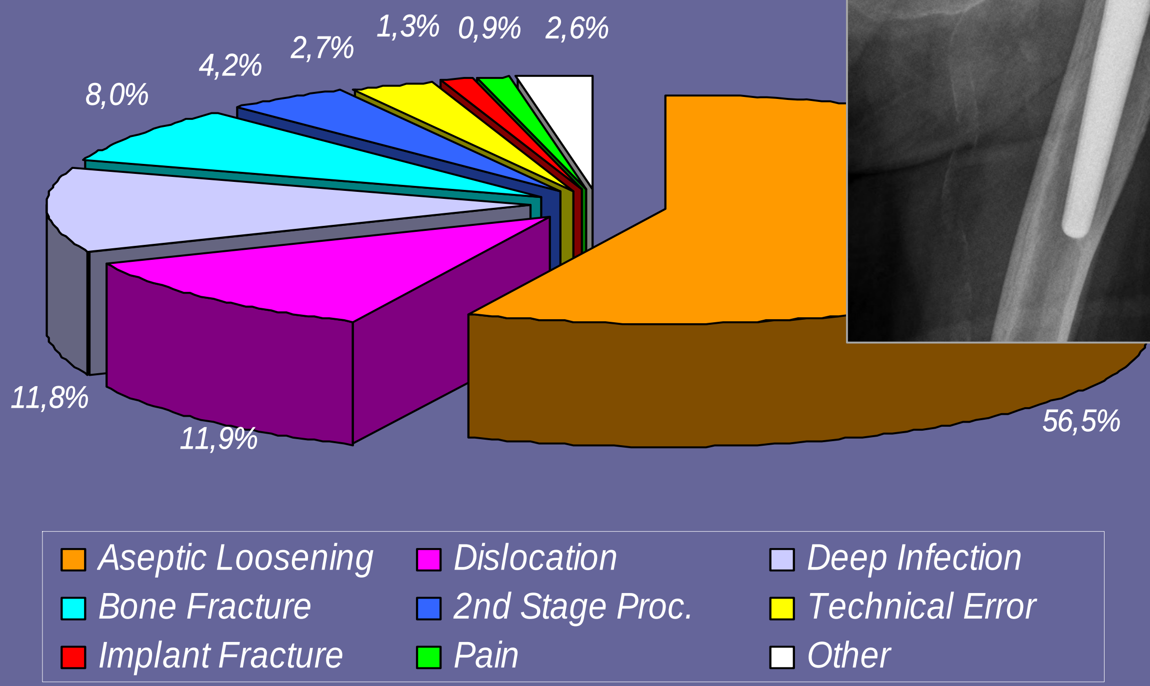


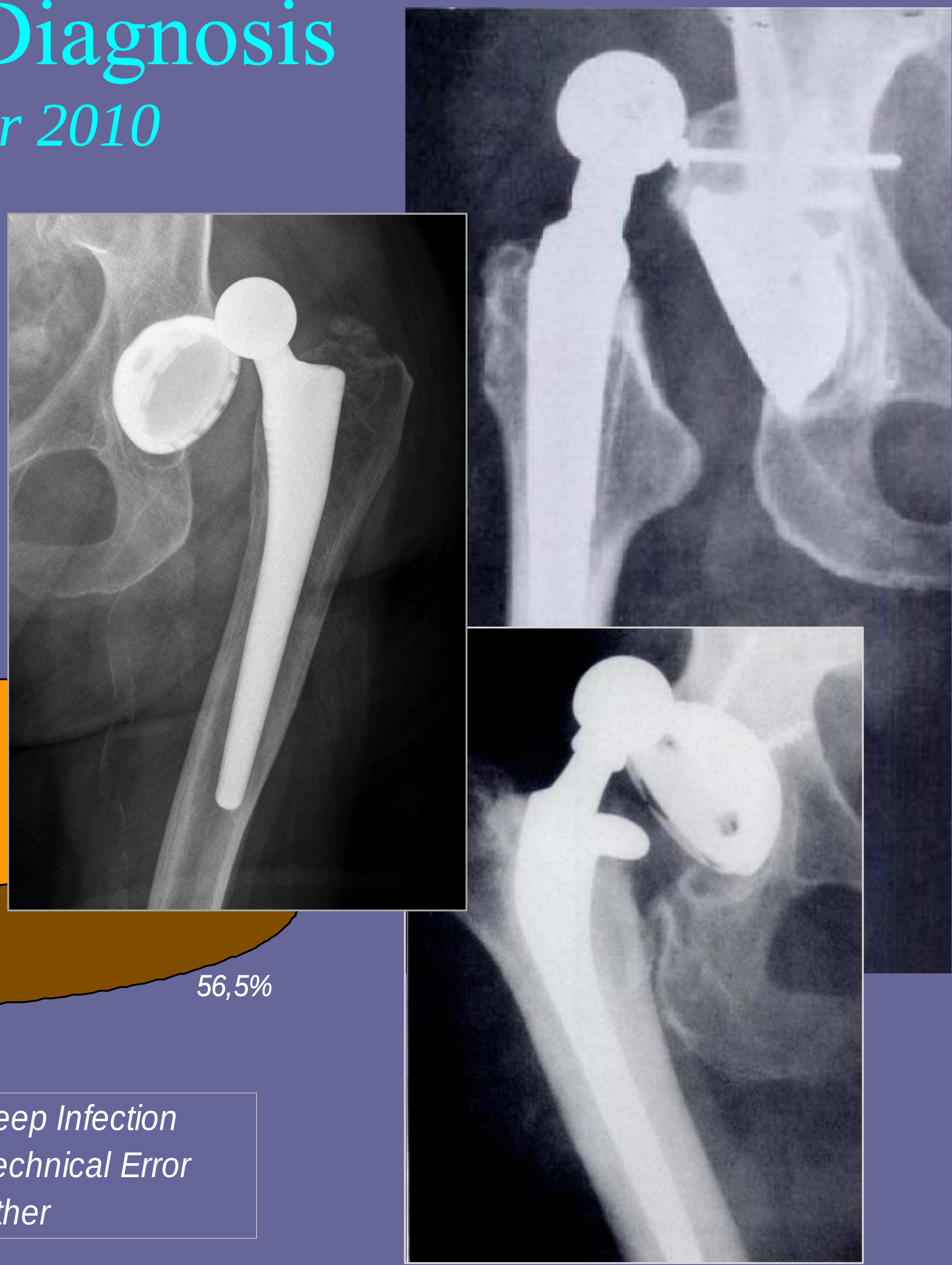
(Mishra & Davidson, 1992)

THR Reoperation by Diagnosis

Swedish Hip Arthroplasty Register 2010

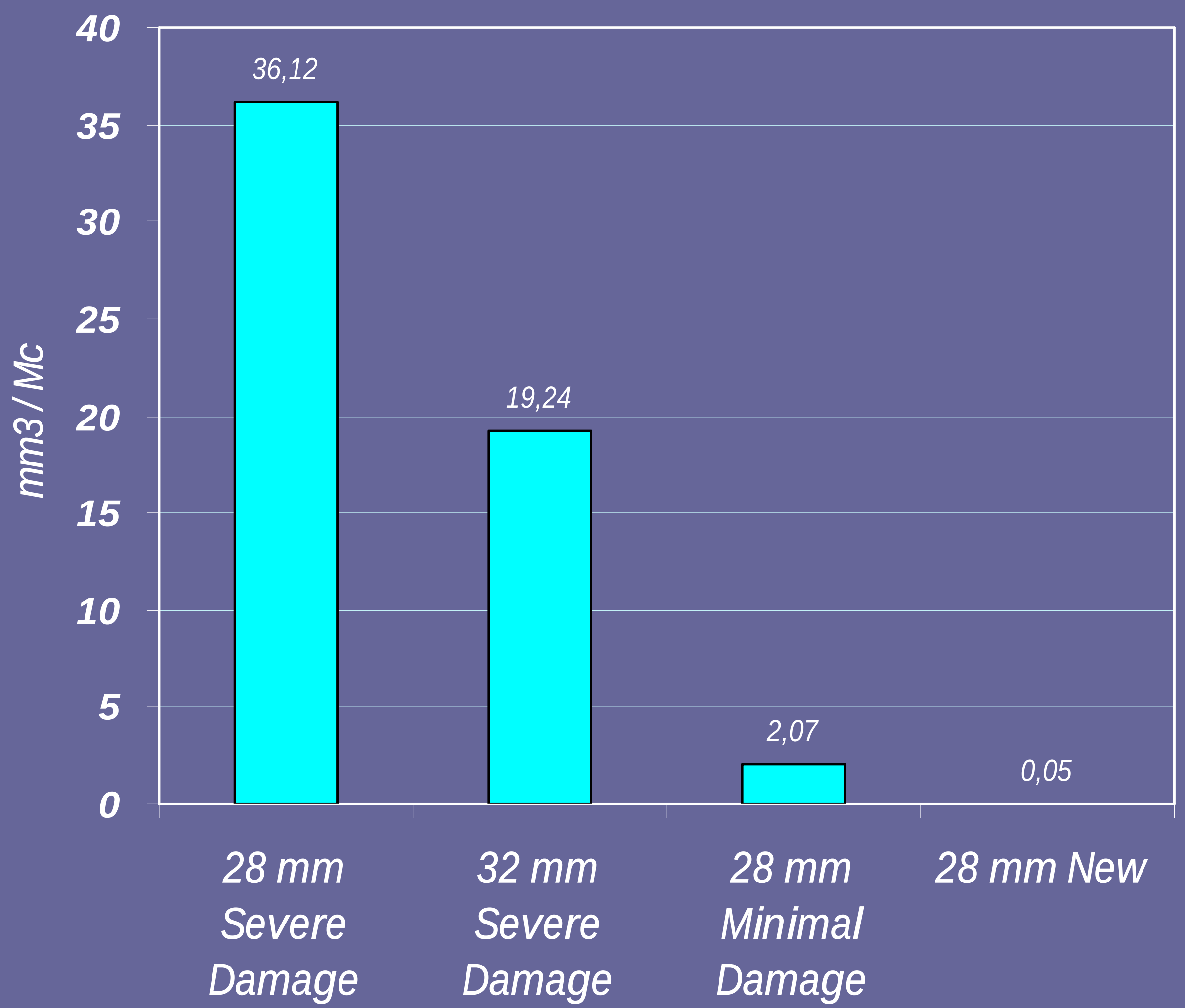
(41.119 Surgeries, 1979-2007)





Ceramized Surfaces in THRs:

Wear UHMWPE Vs. OXZr



(data: Herrera L, et al., 2008)

Ceramized Surfaces in THRs:

OXZr Dislocation Damage

■ CASE REPORT

THE JOURNAL OF BONE & JOINT SURGERY

Damage of an Oxinium femoral head and polyethylene liner following 'routine' total hip replacement

R. W. McCalden,
K. D. Charron,
R. D. Davidson,
M. G. Teeter,
D. W. Holdsworth

From London Health Sciences Centre, University of Western Ontario, London, Ontario, Canada

We present a case of early retrieval of an Oxinium femoral head and corresponding polyethylene liner where there was significant surface damage to the head and polyethylene. The implants were retrieved at the time of revision s length discrepancy just 48 hours after the primary hip replacemen the retrieved femoral head demonstrated loss of the Oxinium laye underlying substrate and transfer of titanium from the acetabular reduction of the index total hip replacement. In addition, the level polyethylene was extensive despite only 48 hours *in situ*.

The purpose of this report is to highlight the care that is require especially with these hard femoral counter-faces such as Oxinium. damage occurring at the time of reduction has not been previousl retrieval of an otherwise well-functioning hip replacement.

The Journal of Arthroplasty Vol. 24 No. 6 2009

Surface Oxidized Zirconium Total Hip Arthroplasty Head Damage Due to Closed Reduction

Effects on Polyethylene Wear

William L. Jaffe, MD,* Eric J. Strauss, MD,* M. Cardinale, BS,† Lizeth Herrera, BS,† and Fred J. Kummer, PhD*

CASE REPORT

Oxinium femoral head damage generated by a metallic foreign body within the polyethylene cup following recurrent dislocation episodes

CrossMark

Orthopaedics & Traumatology Surgery & Research

E. Gibon[a,*], C. Scemama[a], B. David[b], M. Hamadouche[a]

irurgie reconstructive, Centre de recherche de l'orthopédique clinique, ue du Faubourg-Saint-Jacques, 75014 Paris, France
e Paris, UMR CNRS 8579, Laboratoire de sol, structure et matériaux
gnes, 92295 Châtenay-Malabry cedex, France

RCS ADVANCING SURGICAL STANDARDS

ONLINE CASE REPORT

Ann R Coll Surg Engl 2013; **95**: e133–e135
doi 10.1308/003588413X13629960047876

Advanced wear of an Oxinium™ femoral head implant following polyethylene liner dislocation

H Tribe, S Malek, J Stammers, V Ranawat, JA Skinner

Royal National Orthopaedic Hospital NHS Trust, UK

Poster: #2968

Hip Dislocation Increases Roughness of Oxidized Zirconium Femoral Heads in Total Hip Arthroplasty

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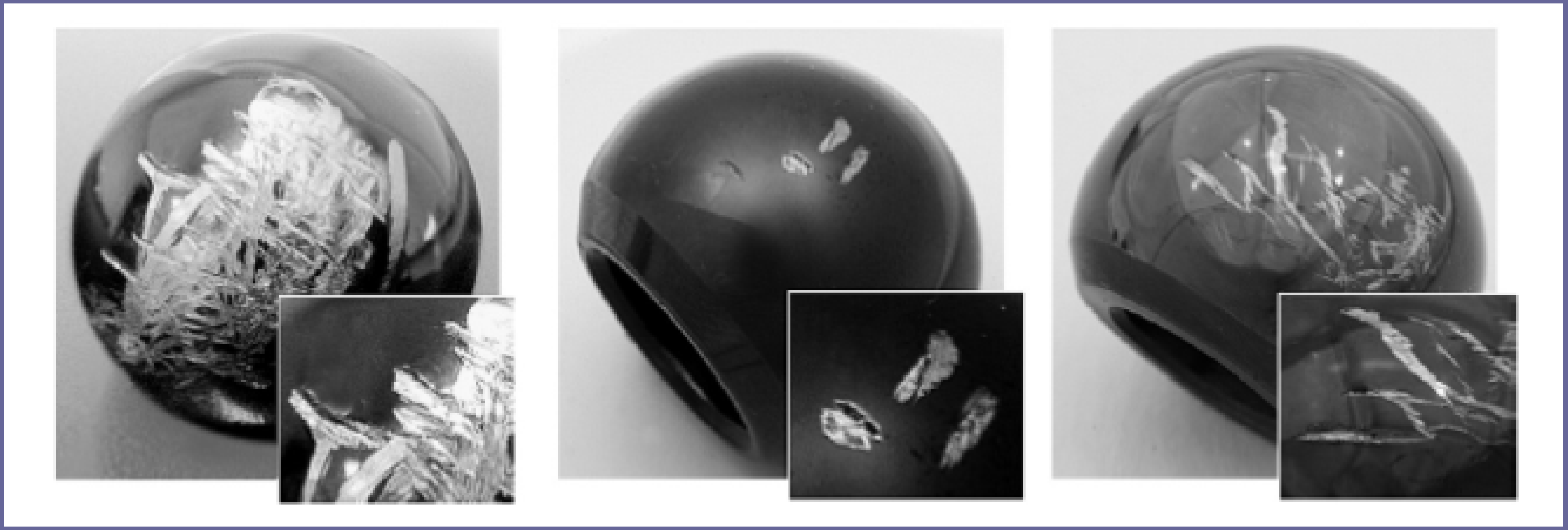
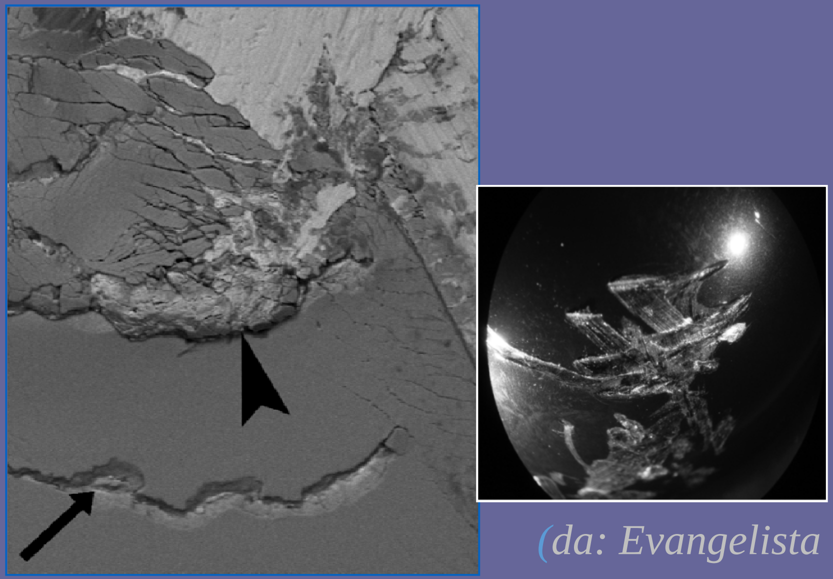
*Email: momoussa1@gmail.com

Ceramized Surfaces in THRs:
OXZr Surface damage



(da : Kop AM, et al.,2007)



(da: Evangelista GT, et al., 2007)

Summary

- The Precursors
- 1970s : The Pioneers
- 1980 – 2004: The Development
    - Alumina
    - Zirconia
    - ZTA – ATZ composites
- Bioceramics in Hip Joint Replacements Today

Thanks for your attention…!

Ready for Coffee Break…?