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POLY012

Bacterial adherence in infected arthroplasties: material differences

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Implant-related infection

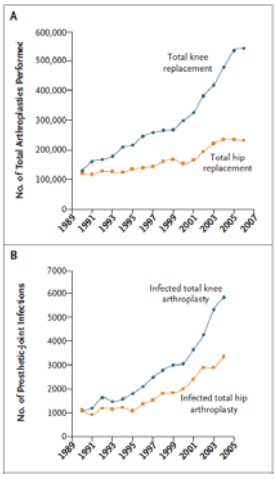
Increasing importance of implant-related infection

- Increasing numbers of TJR
- Increasing numbers of infected TJR (TKR: 1.5-3%; THR: 1-2%)

Table 1. Clinical and Economic Consequences of Infections Associated with Surgical Implants.*

Implant	Implants Inserted in the U.S. Annually	Projected Infections of Implants Annually	Average Rate of Infection†	Preferred Practice of Surgical Replacement	Estimated Average Cost of Combined Medical and Surgical Treatment
	no.		%	no. of stages	U.S. $
Cardiovascular					
Mechanical heart valve	85,000	3,400	4	1	50,000
Vascular graft‡	450,000	16,000	4	1 or 2	40,000
Pacemaker–defibrillator	300,000	12,000	4	2	35,000§
Ventricular assist device	700	280	40	1	50,000
Orthopedic					
Joint prosthesis	600,000	12,000	2	2	30,000
Fracture-fixation device¶	2,000,000	100,000	5	1 or 2	15,000
Neurosurgical — ventricular shunt	40,000	2,400	6	2	50,000
Plastic — mammary implant (pair)	130,000	2,600	2	2	20,000
Urologic — inflatable penile implant	15,000	450	3	2	35,000

Dariouche et al., 2004



Kurtz et al., 2008

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Implant-related infection

Mechanism of implant-related infection:

- Biomaterials may decrease the immune system efficacy
- Implant surface bacterial adherence:
  - Early reversible inespecific adherence
  - Late irreversible adherence:
    - Class II: inespecific bonds
    - Class III: adhesin-receptor bonds

Gristina et al., OCNA 1991; Garvin et al., JBJS 1995

- Implant colonization leads to infection ("race for the surface"): adherence followed by biofilm formation.

Orthopaedic biomaterials and implants may facilitate or impede infection.

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Biomaterial infection in Orthopaedics

- Limited information available about susceptibility to infection in orthopaedic biomaterials.
  - PMMA: inhibits phagocytosis and intracellular lysis. *(Petty, CORR 1978, JBJS-A- 1978)*
  - PMMA: more infection than PE, SS, CrCo. *(Petty et al., JBJS-A- 1985)*
  - PMMA: more infection than CrCo and Ti. *(Cordero et al., JOR 1996)*
  - Metals: porous coating increases surface and infection (more than polished, more in CrCo than Ti). *(Cordero et al., JBJS-Br- 1994)*
  - More cytotoxicity (Co, Ni), more infection.
  - More biocompatibility (Ti, Cr, Mo), less infection.
  - Hydrophobicity increases bacterial adherence *(Donlan et al., Clin Inf Dis 2001)*
- *Yet clinical decisions (i.e. PE exchange) are based on pretended differential infectibility.*

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Aims of the study

- To **isolate the adherent microorganisms** in retrieved implants from patients with infected joint replacements.
- To **quantify** those obtained **from each component** of infected total hip and knee prosthesis after selective sonication of the parts.
- To **analyze** the differential bacterial adherence to the each of the retrieved parts **in each infected joint**.

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Material

- 87 total joint components (51 hip and 36 knee components)
- From 32 patients (20 hip and 12 knee arthroplasties)
- With clinical diagnosis of implant-related infection
- Components under study included:
  - 6 femoral heads
  - 14 femoral stems
  - 14 metal cup shells
  - 13 acetabular liners
  - 9 femoral knee components
  - 4 patellas
  - 11 tibial trays
  - 12 tibial polyethylene
- Predominant material in the component surface was

CrCo in 33, UHMWPE in 27, HA in 17 (5 fully coated) , Ti alloys in 10.

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Methods

- Retrieval study protocol:
  - Sonication of separated components after surgical retrieval (previously published protocol, *Esteban et al., JCM 2008).*
- Microbiological study and quantification:
  - Culture was positive in 75 of the 87 components (all of them from infected joints), and 12 showed more than one microorganism.
  - A ratio of UFC per mm^2 of the implant surface was obtained to compare components.

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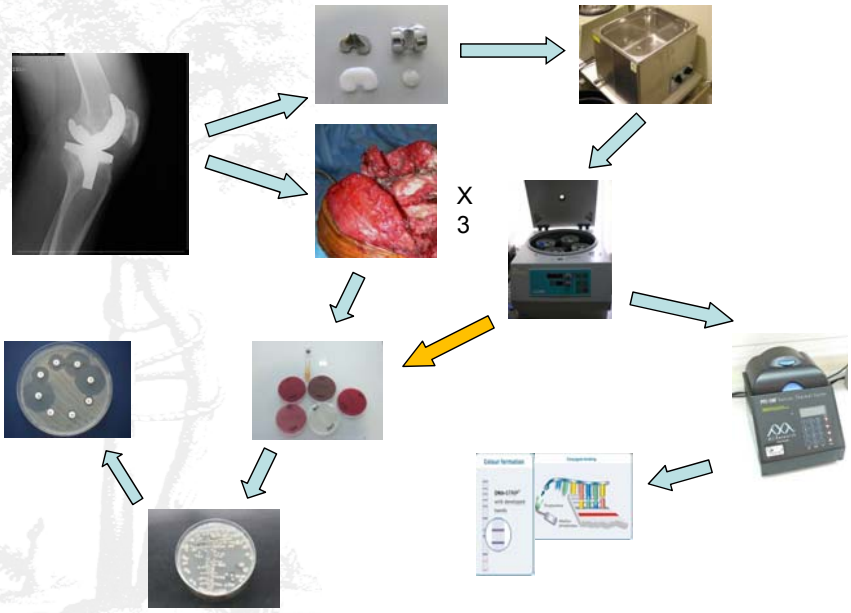

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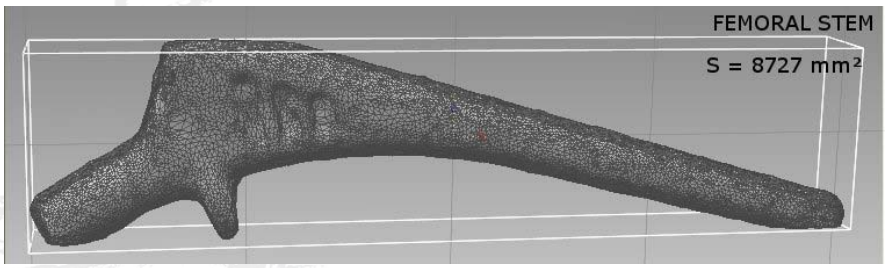
Methods

- Implant measurement and categorization:
  - 6 retrieved joint implants (total 24 components) scanned using a Picza 3D Laser Scanner LPX-60 (Roland DG Corporation, Japan).
  - 3D point cloud data converted into polygon meshes using Dr. PICZA3 software for further file conversion and analysis.
  - Measurements (in mm^2) obtained with PixformTM Pro software.



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Statistical analysis

- Considering *the event of bacterial adherence an independent effect*, descriptive and comparative (Kruskal-Wallis, Mann-Whitney, Chi square tests) statistics were used (CFU/mm^2 variables did not follow a normal distribution in the Kolmogorov-Smirnov test).

- **Mixed linear models with random effects:**
  - The patient is considered the random effect.
  - For both TKA and THA components and for each of them, the models are adjusted for the number of CFU/mm^2
  - Fixed effects being the component and the material

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RESULTS

- Microbiological descriptive analysis on microorganisms:

Microorganism	Mean ±SD CFU/mm²	# components /patients	Polimicrobian cultures	Hips/Knees	Most freq inf
S. epidermidis	2.67±3.73	23/9	7/23	21Hips/2Knees	HA(9)
S. aureus	5.04±5.43	10/4	2/10	6/4	PE(4)
P. aeruginosa	0.2±0.21	5/2	1/5	1/4	CrCo(3)
R. pickettii	3.06±4.83	4/3	0/4	0/4	CrCo(3)
K. pneumoniae	1.55±1.47	4/1	0/4	0/4	PE(2)
S. lugdunensis	4.51±5.33	4/1	2/4	4/0	CroCo(2)
E. aerogenes	2.97±5.7	4/1	0/4	4/0	All
H. kunzii	7.67±6.76	3/1	0/3	0/3	CrCo(2)
Burkholderia sp.	1.21±1.55	2/2	0/2	2/0	Ti(2)
E. coli	0.06±0.05	2/1	0/2	2/0	Ti + PE
Pasteurella sp.	5.09	1/1	0/1	0/1	CrCo(1)
P. acnes	0.05	1/1	0/1	1/0	PE(1)
M. abscessus	0.01	1/1	0/1	1/0	CrCo(1)
G- Anaerobic Bacillus	11.54	1/1	0/1	1/0	CrCo(1)

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RESULTS

- Microbiological descriptive analysis on infections with one component without adherent microorganisms:

Patient #	Hip / Knee	Part/material with negative culture	Microorg. other parts, same Px	CFUs/mm² other parts, same Px	Major adherence part / material in same Px
12	Hip	Shell/HA	*S. epidermidis*	0.01	Stem/HA
18	Hip	Stem/HA	*S. epidermidis*	0.14	Shell/HA
29	Hip	Liner/UHMWPE	*Burkholderia sp.*	2.30	Shell/Ti
83	Knee	Tib surf/UHMWPE, fem comp /CrCo	*S. epidermidis*	0.16	Tibial tray/CrCo
100	Hip	Stem/CrCo	*M. abscessus*	0.01	Shell/CrCo
109	Hip	Fem head/CrCo, liner/UHMWPE	*G- anaerobic bacillus*	11.54	Stem/CrCo
113	Knee	Tib surf/UHMWPE	*Pasteurella sp.*	5.09	Tibial tray/CrCo
124	Knee	Tibial tray/CrCo, tib surf/UHMWPE	*S. epidermidis*	0.05	Fem comp/CrCo
135	Knee	Tib surf/UHMWPE	*R. pickettii*	10.17	Tibial tray/CrCo
137	Knee	Fem comp/CrCo, patella/UHMWPE	*E. coli*	0.1	Tbial tray/CrCo
140	Knee	Fem comp/CrCo, tib surf/UHMWPE	*R. pickettii*	2.03	Tbial tray/CrCo
141	Knee	Fem comp/CrCo, tib surf/UHMWPE	*R. pickettii*	0.03	Tbial tray/CrCo

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RESULTS

- NOT INFECTED COMPONENTS IN INFECTED JOINTS:
  - CrCo: 7 (at risk: 33)
  - UHMWPE: 9 (at risk: 27)
  - HA coated: 2 (at risk: 17)
  - Ti: 0 (at risk: 10)

- When studying independently the adherence of microorganisms to infected joint prosthetic components:

- The presence of positive culture was different among materials (p=0.025, Chi square).
- Significant differences were found in the adhered CFU/mm^2 among components (p=0.018) and materials (p=0.005).
- Lower adherence to UHMWPE than to Ti (p=0.001), but not to CrCo or HA.
- Lower adherence to CrCo than to Ti (p=0.008).

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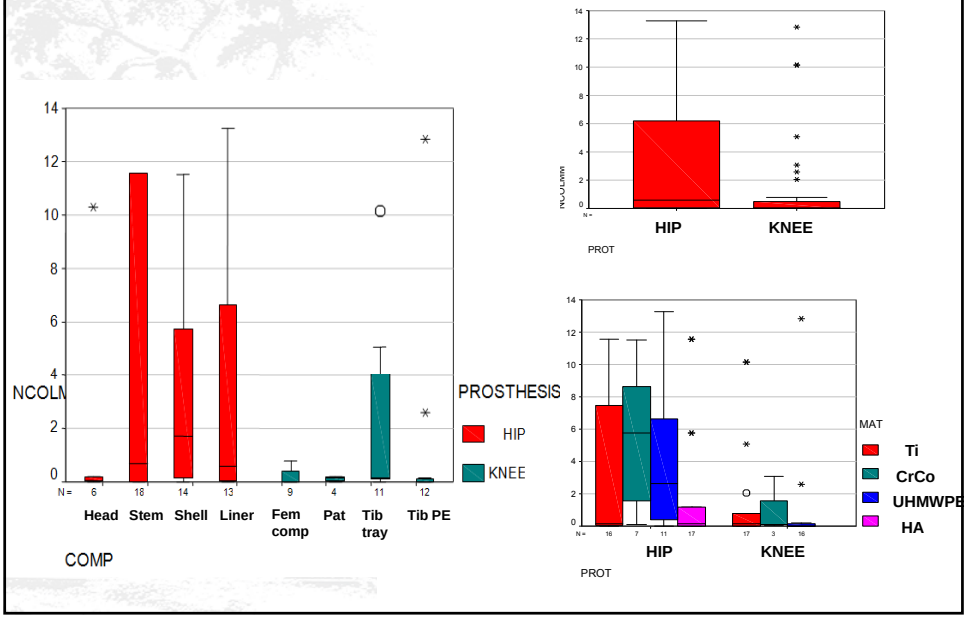
RESULTS



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RESULTS

- When studied mixed linear models with random effects:
  - the patient with his/her infection as a random effect
  - Either the adherence to a biomaterial as a fixed effect (in both the hip and the knee, or in the hip, or in the knee)
  - Or the adherence to a component as a fixed effect (in both the hip and the knee, or in the hip, or in the knee)

All 6 models completed the convergence criteria (p=0.000)

None of them reached significance in the association of a fixed effect (material or component) **to the random effect** (each infection in a particular patient with a particular microorganism).

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Discussion and conclusions

- Similar risk of adherence to different biomaterials in an infected joint.
- The **main determinant of the microorganism adherence** is the particular infection in a particular patient. **Patient and microorganism are the leading factors** of infection, and differences among biomaterials are secondary factors.
- **No clinical confirmation** that polymer infection is higher than metal, as classically studied in animal experiments.
- **No rationale of exchanging one particular component alone** if a joint is infected (i.e. polyethylene selective exchange).
- Complex models, where **the infection of a particular patient by a particular microorganism is the independent variable**, with large number of infected joints are required to clarify the relative and moderate role of a particular biomaterial.

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