DENTAL PROSTHESIS
“TORONTO BRIDGE”:
MATERIALS AND OPTIMIZATION

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Degree thesis of
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What is a **biomaterial**?

«A biomaterial is a systemically, pharmacologically inert substance designed for implantation within or incorporation with a living system» - 6th Annual International International Biomaterials Symposium

«Any substance (not medicines), or combination of substances, with natural or artificial origin, which can be used for any length of time, either alone or as part of a system to treat, enhance or replace any tissue, organ or body function» - Health National Institute

«A biomaterial is a nonviable material used in medical device, so it's intended to interact with a biological system» - European Society

« A biomaterial is any material, natural or man-made, that comprises whole or part of a living structure or biomedical device which performs, augments, or replaces a natural function» - 2nd International Consensus Conference on Biomaterials
Fundamental feature:

- it must be non-toxic
- it must not trigger the body immune response

Biocompatibility wasn't an univocal term

Unified standards

- UNI 9582-3:1990 «Biocompatibility of Medical. Materials and Devices - Bone Implant Test»
- UNI EN 30993-6:1996 «Biological evaluation of medical devices - Tests for local affects after implantation»
- UNI EN 1441:1998 «Medical devices - Risk analysis»
- UNI EN ISO 10993-1:2010 «Evaluation and testing within a risk management process specifies»
Biomaterials are the answer to the human need to replace or integrate tissues and organs no longer operative functionally and metabolically or damaged by diseases or traumatic events.

To rehabilitate edentulism, dentistry proposes the following solutions:

a) dental implants
b) crowns and bridges
c) fixed or mobile prosthesis
The Toronto Bridge is a complete fixed prosthesis introduced by the Swedish surgeon Per-Ingvar Brånemark in Toronto in 1982.

To build a Toronto Bridge, it is necessary:

1. to get the patient dental impression
2. construction of the surgical guided stent of the model on which the calcinable cylinders and the base plate wax are inserted
3. production of the cast metal bar
4. placement of the artificial teeth
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Polyaryletherketone (PAEK) is a family of plastics of the poliketone group.

The PAEKs are aromatic thermoplastics polymers with excellent performances, so they are classified as technopolymers. They are characterized by linear bonds linking ring structures (phenile) to oxygen bridges (ether), and carbonyl (ketones).

Regarding the number and placement of ether and ketone groups, it is possible to define each singular molecular member of this family:

- polyetherketone (PEK)
- polyetheretherketone (PEEK)
- polyetherketoneketone (PEKK)
- polyetheretherketoneketone (PEEKK)
- polyetherketoneetherketone (PEKEK)
The polyetheretherketone (PEEK) is composed by two ether groups and one ketone.

Sold as biomaterial by Victrex® with the trade name of PEEK-OPTIMA™, it has:

- excellent wear resistance, especially in carbon fiber reinforced formulations;
- excellent resistance to a wide range of chemical substances (except sulfuric acid) even at high temperature;
- excellent hydrolysis and pressurized steam resistance;
- high level of purity, with a low level of free ions;
- high thermal stability, it does not require flame retardants.
The PEEK-OPTIMA™ is a highly suitable material for medical devices and prosthetic implants in accordance with the ISO 10993 standard.

Victrex® PEEK-OPTIMA™ polymers considered to realize the Toronto prosthesis are Victrex® 450GL30 with 30% glass fiber and Victrex® 450CA30 with 30% carbon fiber.
The polyetherketoneketone (PEKK) is composed by one ether group and two ketone groups.

Its main characteristics are:

- excellent resistance to fatigue and bending;
- dimensional stability;
- excellent resistance to wear and abrasion;
- compatibility with all sterilization methods;
- X-ray transparency.

Comparative analysis on PEEK and PEKK demonstrated the advantages of the latter, particularly in the dental field because of:

- compressive resistance, up to 80% higher;
- wear resistance, up to three times higher;
- moisture absorption, up to six times less;
- wider possibilities to elaborate process parameters.
Oxford Performance Materials (OPM) was the first company that produced PEKK with the trade name OXPEKK®.

MG – medical grade
IG – implantable grade

OXPEKK® IG was tested following the ISO 10993 standard.

Another company specialized in the PEKK production is Candres-Métaux, which called its polymer PEKKTON®. Really similar to the human bone and dentin, it is particularly used in dental applications.

OXPEKK® polymers employed in Toronto bridge prostheses are OXPEKK® IG200 and OXPEKK® IG230C with 30% carbon fiber.
Optimization: rational process that allows to reach the best solution among all eligible solutions.

Optimization in the context of the development of a project, thanks to mathematical algorithms, permits to choose the most favorable project in terms of eligible feasibility, structural responses and interaction among the various structural components.

The softwares used in this analysis come from the Altair® HyperWorks® suite:
- HyperMesh®
- OptiStruct®
- HyperView®
The first topological optimization of the Toronto prosthesis was made at Politecnico di Torino.

- bridge with six implants
- load distributed as pressure on nine areas
- material: cobalt steel

The optimization analysis provided a rather incomplete structure with disconnected sections.
To obtain a better structure the previous result was acquired and modified:
- definition of no-design space regions
- increase of the number of areas with applied pressure
- plastic material replacement

After the updates and improvements on the original project, the structure was examined by using the HyperView® software.
For the same iteration and the same density value, it is possible to evaluate how different variations affect the final geometry.

1. initial project
2. modified project with nine load zones in Victrex® PEEK 450G
3. modified project with seventeen load zones in PEKK OXPEKK® IG230C

In the PEEK structure there aren’t discontinuities and a more solid construction.
Difference among the structures produced in the two selected polymers:

1. PEKK: Victrex® 450GL30, with 30% glass fiber
2. PEKK: OXPEKK® IG200, virgin resin

The virgin PEKK properties are better than a PEEK added with fillers.
Difference among the structures obtained using:
1. OXPEKK® IG200
2. OXPEKK® IG230C.

The structure realized in OXPEKK® IG230C is harder, with a smaller number of discontinuities.
Concluding my research, I can say that PAEKs, especially PEEK and PEKK polymers, reveal excellent properties that fit really well on the dental implant area.

Considering all the results of my study, I believe that such materials can effectively replace the outdated metal alloys.

Thanks to the topological optimization also, I was able to analyze the prosthesis by considering its structure. Starting from the existing project and making important changes and improvements, I got an optimized structure in my opinion better than the original even if still imperfect and suitable for further refinements.
THANK YOU FOR YOUR ATTENTION

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