SCIENTIFIC REPORT July 2003

ESF – European Medical Research Council Workshop.

Integrated systems for patient dependent treatment planning and execution in dental healthcare.

Milan, Italy 27th – 28th May 2003 at the Starhotel Ritz.

Bringing together expertise in dentistry, biodental materials, numerical modelling, CAD, dental mechanics and experimental techniques.

EXECUTIVE SUMMARY

This ESF based dental workshop was initially developed through various contacts and partners within research laboratories, clinical practice and the university sector within Europe. The essence of the workshop was to bring together experts within the many scientific fields that impinge on dentistry with the aim of identifying a common basis or integrated approach for patient dependent treatment planning. The original selection of the delegates attending the workshop was based on representation throughout Europe while at the same time selecting high quality individuals who had the necessary background and experience in applied dental research at the scientific and clinical levels.

The original workshop programme was developed in 2002 and this consisted of five work packages which were identified as follows: basic dental biomechanics, oral implantology, conservative dentistry and prosthetic biomechanics, orthodontic biomechanics and imaging tools and graphical user interfaces. Each of these themes was designated with two named theme leaders who were responsible for developing the themes and reporting this information to the workshop coordinators. In this way it was considered that interaction, discussions and presentations between the theme leaders and individuals would allow the identification of the technological and scientific requirements necessary to develop an integrated approach for treatment planning and execution in dental healthcare.

The meeting commenced with a presentation by Prof. Rolf Reed, the delegated representative of ESF, who explained the ESF programmes and how these fit within the various European research councils. This was most informative and provided a platform for various questions and points of clarification on the aims and objectives of ESF and the programmes available. Prof. Reed was also available thought the workshop that permitted further contact with the workshop delegates.

The workshop programme commenced with a short presentation given by the coordinators Profs. Middleton/Natali, which was followed by presentations from each participating partner/centre.
A presentation was then given by Dr. Julian Braybrook (UK) on European Framework Programme 6 with particular reference to Integrated Projects which would be one of the routes to further funding. Delegates the discussed and interacted with the theme leaders to enable inputs and subsequent generation of the contents of each designated theme followed this. At a very early stage within the workshop it was agreed that a further theme should be developed to consider the area of Biomaterials. Here Prof. J. Planell agreed to lead this additional theme. At the end of the first day considerable input was being fed to the theme leaders in preparation for collation.

The workshop continued on the second day with the completion of theme inputs. This was followed by the contents of the particular theme being presented to the workshop participants by the theme leaders. This allowed interaction between themes, individuals and expert input such that additional details or areas that overlapped or were repetitive could be revised. On completion of this phase individuals were asked to highlight or comment on omissions or areas of importance or future potential that had not been included. At this stage the multidisciplinary nature of the workshop was noted and that much of discussion had been science based while the requirements of the clinicians were perhaps not as clear as anticipated prior to commencement of the workshop. This lead to further discussions involving the clinical delegates such that their particular requirements could be included in the final theme contents.

Prior to finalising the workshop it was decided that a one further theme be added and this would titled 'Project Management, Control and Dissemination' and Profs Middleton/Natali were designated as leaders to develop this theme. This addition theme was considered essential in that any future proposals involving large multidisciplinary groups or networks required a solid management structure to control input, programme develop, risk and financial control.

Prior to summing up the meeting it was proposal that seven themes (developed form the original five themes) should be grouped as follows:

<u>Clinical Themes</u>
Oral Implantology
Conservative Dentistry
Orthodontic Treatment

<u>Science/Management Themes</u>
Dental Biomechanics
ICT and database Management
Biomaterials
Project Management, Control and Dissemination

It was agreed that in the first instance that new proposals should be submitted both EU Framework 6 and to ESF Network project.

The workshop highlighted the need for international multidisciplinary collaboration and that the development of an integrated system for dental healthcare could have a major impact within the community, economies within dental healthcare and form the basis for the development of new and cost effective dental care both within Europe and worldwide.

It was clear from the outcome of the meeting that the multidisciplinary specialisations of the participants provided an excellent review of the present state of knowledge in scientific and clinical techniques used in dental healthcare. It was also evident that advances in dental materials, dental mechanics, robotics, oral implants, orthodontics, imaging, monitoring techniques and computer based methods are becoming essential tools for the clinician.

It is based upon this outcome that the workshop participants intend to build and develop further collaborative programmes to provide a unified approach for the development of innovative treatment techniques in dental healthcare. This together with integrated evidenced based treatment planning systems will therefore provide a basis for advanced dental and oral rehabilitation in the 21st century.

2. SCIENTIFIC CONTENT OF THE EVENT

It was the primary objective of this workshop to identify the technological and scientific requirements necessary to develop the most effective treatment planning systems in dental health and oral health. To facilitate these systems experts from 12 European centres of research together with clinicians and practicing consultants formed the core of the workshop.

In the framework of the proposed workshop 13 European departments with considerable expertise in dental biomechanics a
nd dental biomedical engineering will meet to coordinate their research efforts in basic dental sciences. The aim was to devise and propose possible technical solutions for the different dental subjects such that clearly defined goals would emerge ***to identify the technological and scientific requirements necessary to develop the most effective treatment planning system in dental and oral health.*** This will then lead to the definition of future research activities in all relevant areas of dental biomechanics and biomedical engineering:

The scientific content of the meeting will be based on the seven themes described below. These will be used as quidelines to initiate the primary objective of the consortium, which is to clearly identify the technological and scientific requirements necessary to develop all aspects of a treatment planning system in dental health care.

CLINICAL THEMES

ORAL IMPLANTOLOGY (Theme 2)
The working group on oral implantology will have to deal with the possibilities of patient dependent modelling of oral implants and the development of numerical simulations for bone remodelling around these implants. Work on this topic has already started within the proposed consortium. Consequently, this would be an appropriate example for the development of an oral implant simulation tool. Interfaces for data exchange of the ongoing research activities have to be adjusted.

CONSERVATIVE DENTISTRY AND PROSTHETIC BIOMECHANICS (Theme 3)
The conservative dentistry and prosthetic biomechanics working group will deal with the patient dependent modelling of filling materials and prosthetic devices. The possibilities of modelling the interactions of the filling with the restored tooth as well as the intraoral loading of bridges have to be analysed.

ORTHODONTIC BIOMECHANICS (Theme 4)
The working group on orthodontic biomechanics will have to deal with the patient dependent modelling of orthodontic tooth movements and active orthodontic devices. A numerical model for the prediction of orthodontic tooth movements based on bone remodelling theories has already been presented by on of the partners. The adaptation of the model to the common software basis is to be checked and performed. Considering this prerequisite, an orthodontic simulation toolbox will be a second demonstrative module.

SCIENCE BASED THEMES

DENTAL BIOMECHANICS (Theme 1)
The basic dental biomechanics group will have to deal with the scientific and technological background for the modelling of all relevant structures: teeth, periodontal ligament, bone and all intra-orally used components, such as filling materials, bridges, dentures, overdentures, orthodontic brackets and active orthodontic devices. The requirements for the experimental validation of the numerical models have to be specified and already existing experimental set-ups have to be tested with respect to their applicability.

GRAPHIC USER INTERFACE (Theme 5)
A key element for the acceptance of computer-aided systems is the user interface. This interface has to combine the whole functions of all toolboxes, take over patient data and process it in a way that the different modules can handle the data. First work on user-friendly graphical user interfaces to visualize treatment situations, plan different treatment steps and providing interfaces to simulation tools has already started. The possibilities of the adaptation to the defined technological and scientific requirements, especially with respect to software development, will be the major task of the working group on imaging tools and graphical user interfaces.

BIOMATERIALS (Theme 6)
Dentistry continues to be one of major clinical disciplines which relies on the development and continued enhancement of biomaterials. These vary from composite fillings, dentures, intra-oral components and a wide variety of bridges, brackets and overlays and crowns. The rapid development of dental implants, facial reconstruction systems and materials requires considerable knowledge of biomaterials and indeed new and advanced biomaterials, bioactive materials, bone substitutes and biodegradable materials need to be developed. This area is rapidly expanding as a result of clinical and social needs and the workshop will consider this as an addition theme to those originally proposed.

MANAGEMENT AND ORGANISATION AND PROJECT CONTROL (Theme 7)
Management and project control is now included as separate identified task that is of prime importance for the success of preparing, implementing and communicating research within a specified programme. Here problem solving approaches, support systems, management of multidisciplinary projects, risk assessment and financial/audit control will required to ensure that the aims and objectives the objectives of the proposals developed are met in full. Sections on intellectual property, standards and regulations, working with large-scale organisations and public awareness will also be considered.

3. ASSESSMENT OF RESULTS

The following themes 1 – 7 were developed through interaction, discussion, research input and future needs in dental healthcare. Theme 8 lists some of the main inputs required when considering the development of major projects particularly those within EU Framework Programme 6. This output will form the basis for future applications to ESF the European Union and other international grant awarding bodies (See list in section 'future directions' below)

Theme 1: Dental Biomechanics

1. maxillofacial and mandibula bone tissue

Mechanical properties: stiffness, strength, fatigue resistance, fracture, time dependent aging and assessment.
Bone Structure: structural levels, density, remodelling – mechanotransduction
Biochemical composition:

2. Teeth and oral health

Mechanical properties: stiffness and strength – behaviour under static and dynamic loading, mechanical wear resistance.
Composite structure of enamel and dentine.
Influence of surrounding environment: effect of temperature changes, chemical resistance, microbiological factors, teeth root resorption, effect of ph levels.

3. Periodontal tissue (Ligament)
Stiffness, strength, time dependency, development of constitutive equations. Modelling of micro cellular structure.

4. Forces acting in the maxillo-mandibular complex. Muscular-skeleton modelling: stiffness of the mandibular in maxillo-facial biomechanics: possible fracture of the mandibular by progressive atrophy, effect of different loading – compression, shear, complex 3D

5. FEM analysis and introduction of stress-strain relationships in dental biological systems. 2D and 3D modelling, physical nonlinearity, geometrical non linearitly.

6. Characterisation and identification of tissue parameters using mixed analytical/computational/experimental methods. This includes use of imaging techniques and motion analysis.

Theme 2: Oral Implantology

Tissue engineering:
Scaffold and microsensors (eg. Chemical and indentors).
Bioreactor development of supporting tissues.
Regeneration of supporting tissue: replacement of pdl and direct bone anchorage.
(Engineering) Design approach for restoration of mastication: dental function: problem solving approach:
Balance : Risk : Challenge: implants OK however regeneration approach should yield new solutions where current solutions do not yield good results (lack of bone)

Guided Regeneration
Controlled loading
Controlled biology/biochemistry
The above fits with mechanofunctional knowledge based materials: theme designed for certain purpose.
Sensorial devices and procedures to measure integration/regeneration of he biological structure + CIS (to be linked to progress in image modalities)

Industrial Input
Materials
Sensors
Manufacturing
ICT, OO, CIS with robotics

Improved QoL, systems for better diagnosis, tissue eng, new sensors.
Reduced needs for animal testing.
Pre-clinical testing and design by combined computer modelling and in vitro testing. This fits with in-vitro(bioreactor development), standardisation laws and standardisation regulations.
Biological and non-biological surfaces – entities.
Proteins, cells – linked to genes – but would come later.
Social health care costs.

Theme 3 – Conservative Dentistry

Integrated evidence based treatment planning systems for dental rehabilitation
Should be web based
Modular: simple restorations
Cariology
Crowns and bridges
Implants
Periodontology
Orthodontics

Ascess to GDP's - annual fees
Industrial partners –GSK / P& G
Accelerated test methods for predicting failure of crown adhesion – computational modelling and stress analysis of crown deformation.

1. swallowing minimal content
2. chewing
3. grinding

Practical measurement of residual stress in polymer restorations
Influence of load and bone resorption.
PMMA and dentine bases
Patient dependent modelling of implants – to tailor
Extension of cerone system(ceramic crown) to include bite forces – optimisation of crown design.
Bridges, intracoronal – within crown – pressure sensitive films.
Individual treatment plans
Better visualisation from x-ray/scanning to guide planning.
Tools for caries identification, ultrasound electrical resistance – early markers for caries identification.
Tooth structure behaviour in presence of restoration – re effect of tooth survival.

Caries susceptible – varies between patients.
Cavity preparation – drills, lasers, root fillings, chemical based solutions.
Amalgams last for 12years – tooth damaged composites last 5 yrs????
Use antibiotics systematically for treatment of caries – is resistant to bacteria – generic

Theme 4 – Orthodontic Treatment

1. Diagnostic tools - 3D facial imaging

'A non invasive alternative to dentofacial radiography'

1.1 Three dimensional facial imaging offers the opportunity to establish normative linear and volumetric facial measurements for all age groups. This would provide a valuable orthodontic diagnostic tool but would require the development of software to produce the 'average' composite face from cross sectional data.
1.2 Longitudinal 3D facial data can be used to illustrate facial growth and treatment changes. Given sufficient data, a neural net could be developed to predict growth changes, treatment changes and age changes.

2. Appliance therapy

'Clinically valid FE models'

2.1 Orthodontic attachment
The valuation of orthodontic attachment requires the development of a clinically valid 3D FE model that reproduces the geometry and physical properties of the tooth adhesive and bracket and the interfaces of the adhesive with enamel and bracket base. Load cases reproducing the forces and dynamics of the chewing cycle would need to be developed.

2.2 Tooth movement
Orthodontic alignment.
The physical properties of orthodontic aligning arch wires have been widely studied in vitro. However, the resistance to tooth movement introduced by the bracket/wire interface, method of arch wire ligation and dental contact point interaction will significantly influence the effectiveness of aligning forces. Similarly, the quality of tooth translation during orthodontic space closure is often influenced by friction at the bracket/wire interface and force direction, magnitude and decay. In addition, the moment to force ratio delivered and the influence of masticatory forces also must be considered. The development of a 3D FE model that reproduces these parameters and allows dynamic tooth would provide an invaluable test bed for orthodontic mechanics.

Specialised materials SMA, arch wires and friction, locking etc., anchorage using implants.

Additional Treatment planning

The models described rely on the establishment of the material properties of dental, alveolar and periodontal tissues, the dynamic masticatory load case and the complex interactions at the bracket/wire interface. Although ambitious, such a model would ultimately allow the development of an expert system that could help prescribe orthodontic mechanics for the correction of a presenting malocclusion. This would include maxillofacial surgery, oral implantology and pre-surgical simulation of tooth movement with visualisation.

Theme 5: ICT and database Management

As item 1, theme 5 should form the backbone for the clinical application themes 2,3, and 4.
Theme 5 could be renamed as communication and interfacing.
Theme 5 has two distinct sections:

1. ''Internal'' communications: exchange of data between partners – need for inventory of hardware and software used. Central question: who needs what from whom???

2. ''External communications : development of toolboxes for:
   diagnostics
   treatment/treatment planning
   instructional/educational tools
   data bases for modelling

Need for inventory of wishes/demands from the clinical field – exploitable deliverables

Theme 6. Biomaterials

Materials properties: composite materials, biochemistry, environmental.
Micro-chemico analysis
Biomaterials, including coatings, bioreactive materials
Bone cements, bio resorpable implants,
Hybrid glasses and HAP coatings
Surface treatments and coating techniques
Intelligent coating systems and coating morphology
Sensors, Forces Biochemical sensors
Tissue regeneration and development of scaffolds for tissue reconstruction
Growth factors tfgbeta etc.
Spongy structures 1 – 30 microns (could cover wider area?)
Tissue seeding into scaffolds

Theme 7: Project Management, Control and Dissemination

Management of large scale projects: Project control, workpackage control outcome, integration and dissemination.
Financial and Audit Control.
Road Map: this must be carefully developed
Communications between groups.
Problem solving approach – new support systems - new ideas low amounts of bone
The above themes can be grouped as follows: Theme 1, 5 and 6 are science based themes linked to themes 2,3 and 4 (clinical themes)
Commercialisation: software, diagnostics scanning, instruction, teaching.
Standards and Regulations
Inclusion of large scale commercial organisations (GSK, P&G, Astra etc.)
Also inclusion of SME's
Public Awareness
Management of multidisciplinary nature of project.
Dental informatics – evidence/knowledge based.
Include other countries: Poland, Slovakia etc.

Reduce costs and social impact
Training and manufacturing
Protection of IPR and Patenting.
Quality Control/certification

8. GENERAL COMMENTS FROM THE FLOOR (from open discussion)

Sustainable knowledge based dental technologies
Some Key Words:

Integrated systems
Treatment planning
Improved healthcare
Knowledge based
Patient orientated/dependent
Evidenced based
Non-invasive
Start-end procedure planning
Monitoring (prevention)
Innovation (final goals)
Long lasting/durable
Materials – technology
Individual (custom made procedures)
Technology transfer to clinical practice
Restore and Maintain
Final gaol definition
Current challenges
Costs
Multidisciplinary
Manufacturing
Training
Development of durable
Dentures for the 21st century

- Technological innovation for patient orientated sustainable oral healthcare.
- Integrated evidenced based treatment planning system for dental and oral rehabilitation

Future Directions

The above topics and seven themes form the basis of a definition phase that will allow further applications to be developed in the area of dental research.

These applications will include the following:

Large scale projects and networks involving the majority of the workshop participants and further partners including industrial and manufacturing companies. It has been agreed that two such projects should be developed these being and INTEGRATED PROJECT within the EU Framework Programme 6. This will be lead from groups in BELGIUM, ITALY and the UK and it has been agreed that the project will be managed by LGC/NPL. It has already been clear by Dr. J. Braybrook of LGC that such projects are difficult to fund at that considerable industrial funding will be require.

An application will be made to ESF to fund a Network for Dental Research. This will be European based and will involve high quality pro-active groups with the aim of providing a basis for multidisciplinary dental research.

An application is presently being developed to consider imaging and computer based techniques for facial reconstruction. This will be submitted under the EU FP6 programme under the STREPS scheme.

It is considered that this workshop and outcomes has been the prime motivator in developing these proposals and that further proposals will no doubt take place as a result of bringing together this considerable expertise.

4. FINAL PROGRAMME

27th May 2003

Programme chaired by Prof. John Middleton and Prof. Arturo Natali

12.00 - 12.30	Presentation of ESF Mission by Prof. Rolf Reed
12.30 –1.00	Organisation and introduction of the consortium.
1.00 – 2.00	Lunch
2.00 – 3.00	Presentation of the expertise of each partner (5 minutes each)
3.00 – 3.30	Presentation of EU Framework Programme 6 by Dr. Julian Braybrook
3.30 - 4.00	Break
4.00 – 6.00	Development of Theme topics
8.00 – 11.00	Working Dinner

28th May 2003

9.00 – 10.30	Theme leaders to interact to develop links between groups and to synchronise topics, expertise and knowledge base.
10.30 – 11.00	Break
11.00 – 1.00	Finalise Themes
1.00 – 2.00	Lunch
2.00 – 3.30	Presentation and fine tuning of Themes
3.30 – 4.00	Break
4.00 – 4.30	Open discussion and inclusion of additional topics
4.30 – 6.00	Consortium Development for proposed advanced research project in Dental Healthcare
6.00	Closing Remarks

Workshop Theme Leaders

Each Theme was headed by two workshop Team Leaders who were responsibility for developing the topics and expertise available in each Theme. This was collated into feasible topics, which represented the expertise of the consortium together with other input that is considered essential. The five themes and Leaders were as follows.

Theme 1.	I. Knets	C. Provatidis
Theme 2.	J. Vander Sloten	S. Clift
Theme 3	J. Rees	P. Tomlins
Theme 4.	J. Knox	C. Bourauel
Theme 5.	M. Dalstra	J. Subke

5. FINAL LIST OF PARTICIPANTS

List of participants that attended the workshop including full postal address and email.

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Prof. Rolf Reed
ESF Representative

6. STATISTICAL INFORMATION ON PARTICIPANTS

Number of participants: 24.

Age structure: Between 30 – 40years: **7 participants**
Between 40 – 50years: **8 participants**
Between 50 – 65years**: 9 participants**

Countries of Origin:
Belgium: 3 (1 Professor, 1 Clinical Dentist, 1 Senior Researcher Assistant)
Denmark: 1 (Senior Lecturer)
Finland: 1 (Consultant Dentist)
Germany: 2 (1 Professor, 1 Senior Lecturer)
Greece: 1 (1 Professor)
Latvia:1 (1 Professor)
Italy: 5 (4 Professors, 1 Senior Researcher Assistant)
Portugal: 1 (1 Professor)
Spain: 1 (1 Professor)
UK: 7 (2 Clinical Dentists, 1 Prof, 1 Sen. Lecturer, 2 Sen. Scientists, 1 Sen. Research Asst)
NB: The ESF Representative has not been included in the list of Countries of Origin.

9 EU Nations
1 Non – EU Nation