

# Computer simulation of Xunplates – micro-mechanical devices for moving bones in a cleft palate

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## SYMULACJA KOMPUTEROWA XUNPLATES – MIKROMECHANICZNYCH URZĄDZEŃ DO PRZESUWANIA KOŚCI W ROZSZCZEPIE PODNIEBIENIA

### Abstract

The paper presents an initial study on the construction of a system of micro devices placed under the oral mucosa and exerting a pressure on the cleft palate in order to move it in the desired direction of growth. The micro-mechanical device is activated by small impulses of an electromagnetic field. There is no direct connection between the sterile parts placed under oral mucosa and the outside world, which protects a child from contamination. That is why the treatment may last several months. Virtual reality is going to answer some questions about the system (not built yet).

A virtual patient – a newborn with a cleft palate was created as a deformation of a 3D model of a newborn skull. The 3D data were obtained using Computer Tomography. Several types of brackets – components of the Xunplates system were simulated. Virtual reality allowed several analyses of actual bone shape and the planning of its target. The system calculates intermediate stages using three-dimensional morphing. A micro-mechanical device will be built on the basis of the virtual reality tests, which helped to make improvements in the system without building expensive prototypes. New scenario of cleft palate treatment was proposed after computer simulations.

### Streszczenie

Autorzy prezentują wstępne badania nad konstrukcją systemu mikrouządzeń umieszczanych pod błoną śluzową i wywierających siły na kości rozszczepionego podniebienia, aby stymulować w nich odpowiedni kierunek rozwoju. Urządzenie jest aktywowane słabymi impulsami pola magnetycznego. Nie ma bezpośredniego połączenia między umieszczonymi pod śluzówką urządzeniami i światem zewnętrznym, co chroni pacjenta przed zakażeniem. Dzięki temu leczenie może trwać wiele miesięcy.

Badania w wirtualnej rzeczywistości pozwoliły odpowiedzieć na wiele pytań dotyczących niezbudowanego jeszcze systemu. Wirtualny pacjent, dziecko z rozszczepem podniebienia zostało stworzone przez deformację modelu trójwymiarowego czaszki noworodka. Informacje przestrzenne zostały uzyskane ze spiralnej tomografii komputerowej. Kilka rodzajów elementów Xunplates(R) zostało zasymulowanych. Badanie pozwoliło na szereg analiz zmian w kości i planowanie kształtu docelowego. System wyliczył stany pośrednie metodą trójwymiarowego morpingu.

System zostanie zbudowany w oparciu o symulacje komputerowe, które pozwoliły na udoskonalenia bez budowania drogich prototypów. Nowy scenariusz leczenia rozszczepu podniebienia został zaproponowany na podstawie wyników symulacji komputerowych.

Key words: cleft palate, orthodontic systems, virtual reality

**INTRODUCTION**

Currently used orthodontic systems, both fixed and removable, have some limitations. Their natural force insertion point is the crown of a tooth or the mucosa, which determines how they work: by changing the inclination of the tooth or by axial movement. In either case, a force configuration is unfavorable, far from the centre of the tooth. These disadvantages are not present in the sub-mucosal orthodontic system.

The micro-plates as an attachment for the forces were introduced in Orthoanchor (r) orthodontic system (1, 2). The main disadvantage of this system is the presence of intra-oral wires and direct contact between the bone and the outside world. This problem is to be eliminated in our Xunplates system. All parts of the system: pulling/pushing brackets, wires and micro-plates are planned to be inserted under the surface of the mucosa or periosteum. No part of the system protrudes through the mucosa, which means that it remains sterile. Placed under mucosa, it allows axial tooth movement in favorable, central force insertion point. The most important feature of this system is that it allows bringing the alveolar bones close together in a cleft palate. The application of forces with implanted Xunplates will prevent improper frontal growth and will model bone shape to restrict the size of a future transplant.

The initiation of treatment too early or too late is also a problem we have to face in maxillofacial reconstruction. Early surgical treatment of cleft palate causes inhibition of frontal development of the maxilla after surgical intervention. Late surgical treatment, on the other hand, causes improper bone formation – a wide cleft that makes reconstruction extremely difficult (3, 4, 5).

So what is the ideal solution? Not to inhibit or depress bone growth and to move and/or bend the bone before merger surgery, as in the treatment scenario proposed as a result of our simulations.

Virtual Reality (three dimensional graphics) programmes are widely used in industry for testing non-built (as yet) systems such as cars, airplanes etc. Computer simulation allows for the improvement of such systems without building several expensive prototypes in the process

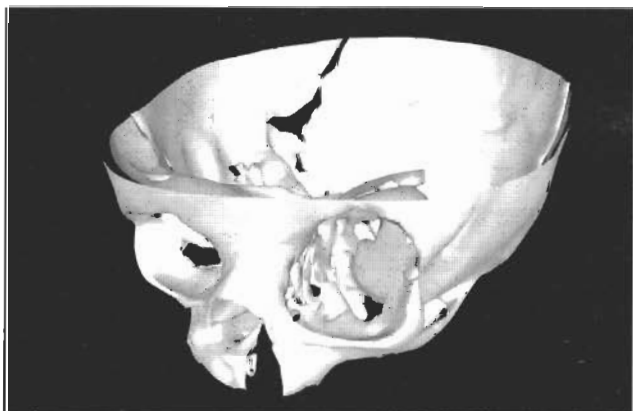


Fig. 1. Virtual Patient.

(6, 7, 8, 9). It was obvious that constructing a prototype of a micro device for moving bones in cleft palate would be costly and difficult. That is why we decided to use computer simulation before building the first real prototype.

This paper presents an initial study on the construction of a system of micro devices placed under the mucosa and exerting pressure on the cleft palate to move it into the desired direction of growth.

**AIM**

The aim of the work was to create a system for controlling the rebuilding of the palatal and alveolar bones with an orthodontic system placed sub-mucosally and driven by impulses of an electromagnetic field.

During this study we wanted to test this system using Virtual Reality before building expensive prototypes.

**METHOD**

The virtual patient – a newborn with a cleft palate, was created as a deformation of a 3D model of a newborn skull (see Fig. 1). The 3D data were obtained using Computer Tomography (we used internet resources; no child was exposed to radiation for this study). Using computer simulation, based on the literature (7, 8, 9, 10) and radiographs of a cleft palate, bones were removed and a large cleft was created. A smoothing filter was applied locally on the cleft to make it more natural.

We superimposed the virtual models of our Xunplates system onto a skull model. Xunplates is a system of micro-plates, brackets and titanium wires designed to be inserted during atraumatic surgery under local anaesthesia. Micro-plates tightened with screws are used as bone attachments. The key component of the system is a sub-mucosal micro-mechanical device driven by impulses of an electromagnetic field, which can move the micro-plates in a chosen direction.

The insertion points are chosen earlier using computer tomography. Standard Helical CT with 3D reconstruction

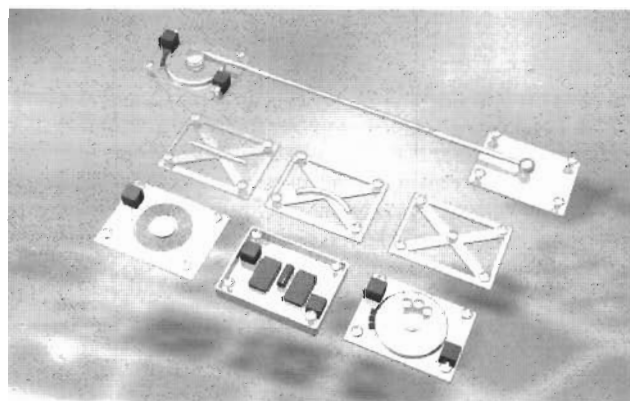


Fig. 2. Components of the Xunplates system: a.) palate growth stimulator; mechanical components: b.)angular, c.)linear and d.)corner wire retainers; electric parts: e.)solenoid – the power source of the system which works like an antenna transmitting electrical power, f.)electronics controller box, g.)piezoelectric engine for wires. On the figure all the boxes are showed opened; normally they will be closed standard size titanium boxes.

tion and CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) module can be used. Prepared leads will be used for the insertion of elements without visual control. After (2 mm) wounds have healed, the moving process will begin. The micro-mechanical device will be activated using small impulses of an electromagnetic field and will exert a small, constant force on the micro-plate. This process may last several months, because there is no direct contact between the sterile sub-mucosal parts and the outside world. We can choose the direction of movement by turning several micro-devices on and off. Electric power and control data are transmitted through the mucosa using solenoids. An electronic system was planned as a One-wire® bus, commonly used in microcontroller's technology. The level of magnetic impulses used in the device is much lower than that emitted by a cell phone, and should not have biological implications.

During this simulation of Xunplates and a bone displacement, a standard 3D Studio® from Autodesk was used as a software platform. Calculations and rendering were performed using 1,5GB RAM Computer, currently one of the most powerful graphic workstations available.

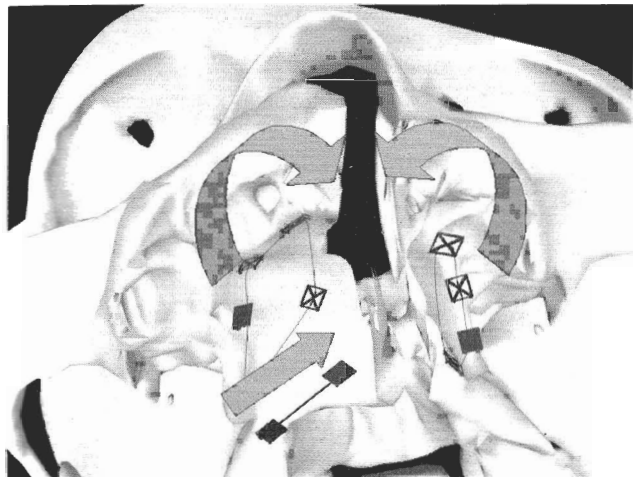


Fig. 3. Relation between stimulated, desired direction of growth, applied forces and device construction. The whole system can be seen in action: the wire ring for alveolar bone bending, palate growth stimulator and the other brackets.

## RESULTS

3D simulation was found to be a useful tool for the virtual testing of new possibilities of treating cleft palate. The 3D model of the cleft palate allowed force planning and simulation of bone movement.

Several types of brackets – components of the Xunplates system were simulated (see Fig. 2).

We have tried many arrangements of the system on our virtual patient. One such arrangement, chosen for its best application in achieving the desired force directions, is illustrated in Fig. 3. The whole system can be seen in action: the wire ring for alveolar bone bending, palate growth stimulator and the other brackets.

We have tried to simulate bone changes using the three-dimensional morphing mechanism of our software pack. Three intermediate stages are illustrated (Fig. 4).

The following scenario of cleft palate treatment was proposed after computer simulation:

*I. Planning of modeling cleft palate:* Spiral computer tomography; Analysis of the actual bone shape and planning of the target shape; Determination of intermediate stages using three-dimensional morphing. Determination of insertion points for Xunplates using finite element force calculation, based on the skull model from computer tomography. The surgical leads are created using computer engravers or stereo photolithography.

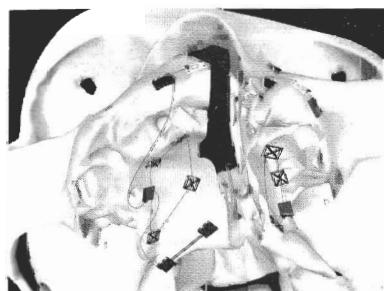
*II. Primary Surgery:* Atraumatic procedure, sedation and local anesthesia; Small (2×2 mm) mucoperiosteal flaps are raised; Application of brackets with micro screws in pre-determined locations using the prepared leads; Connect of brackets using needle-sized tunnels in the uncut mucosa; wires can be inserted without cutting the mucosa and without visual, thanks to the prepared guide ways.

*III. Post surgical period (several months):* Stimulation of the system using impulses of an electromagnetic field; Radiological control of bone changes.

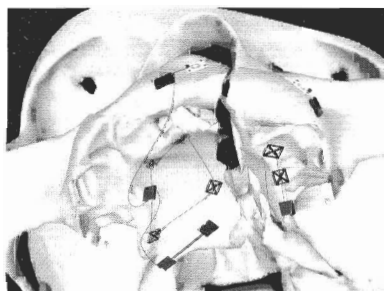
*IV. Secondary surgery:* Removal of the system; a small transplant, if needed; Suturing of the small cleft.

Other possible applications of the system have been noticed, such as post-oncological surgery reconstructions, enhancement of the zygomatic arch and frontalisiation of the maxilla in progeny, plastic surgery.

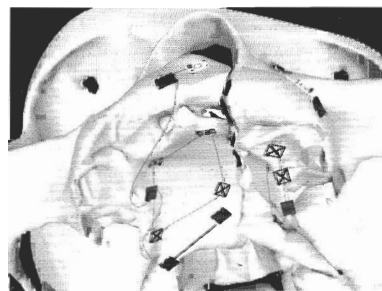
The determination of insertion points for Xunplates using finite element force calculation is possible, but has



a. Start of treatment



b. Intermediate stage



c. End of treatment

Fig. 4. Morphing – the simulation of treatment.

not been performed yet; because of the poor skull model applied (lack of internal data). The biological considerations of this system are outside the scope of this study and must be investigated in a future study using an animal model.

#### CONCLUSION

Virtual reality helps to answer some questions about a non-built as yet system for moving bones in cleft palate. It allows for several analyses of the actual bone shape and the planning of their target shape based on spiral computer tomography. One of the most valuable applications is the determination of intermediate stages using three-dimensional morphing.

A micro-mechanical device will be built based on virtual reality tests, which have helped to make improvements in the system without building expensive prototypes.

The system demonstrates a new possibility of cleft palate treatment. Other possible applications include post-oncology reconstructions, plastic surgery and maxillofacial surgery. The system needs intensive animal testing and development before it can be used on humans.

#### ACKNOWLEDGEMENT

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