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Original Article

Application of three-dimensional prototyping in planning the treatment of proximal humerus bone deformities☆

Fernando Carlos Mothes[a], *Almiro Britto*[a], *Fábio Matsumoto*[a], *Marco Tonding*[a,*], *Rafael Ruaro*[b]

[a] *Grupo de Cirurgia de Ombro, Santa Casa de Misericórdia de Porto Alegre, Porto Alegre, RS, Brazil*
[b] *Hospital Unimed Nordeste, Caxias do Sul, RS, Brazil*

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ABSTRACT

Objective: To describe the use of three-dimensional prototyping or rapid prototyping in acrylic resin to create synthetic three-dimensional models in order to promote the understanding of bone deformities of the shoulder.
Methods: Five patients were analyzed between ages of 11 and 73 years old, treated between 2008 and 2013 with glenohumeral deformities that required a more thorough review of the anatomical alterations, for whom three-dimensional prototyping was performed.
Results: Patient 1 was treated conservatively and is awaiting humeral head arthroplasty if symptoms get worse. Patient 2 underwent a valgus proximal humerus osteotomy secured with pediatric locked hip plate according to a prior assessment with prototyping. Patient 3 underwent a disinsertion of the rotator cuff, tubercleplasty and posterior reinsertion of the rotator cuff. Patient 4 underwent an arthroscopic step-off resection, 360-degree capsulotomy, and tenolysis of the subscapularis. Patient 5 underwent a reverse shoulder arthroplasty with an L-shaped bone graft on the posterior glenoid.
Conclusions: Rapid prototyping in acrylic resin allows a better preoperative planning in treatment of bone deformities in the shoulder, minimizing the risk of intraoperative complications in an attempt to improve the results.

☆ Study conducted at Grupo de Cirurgia de Ombro, Santa Casa de Misericórdia de Porto Alegre, Porto Alegre, RS, Brazil.

* *Corresponding author.*
E-mail: marcotonding@gmail.com (M. Tonding).

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O uso da prototipagem tridimensional para o planejamento do tratamento das deformidades ósseas do úmero proximal

Palavras-chave:
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RESUMO

Objetivo: Descrever o uso da prototipagem tridimensional ou prototipagem rápida em resina acrílica na criação de modelos sintéticos tridimensionais para facilitar o entendimento das deformidades ósseas do ombro.

Métodos: Foram analisados cinco pacientes entre 11 e 73 anos, tratados entre 2008 e 2013, com deformidades glenoumerais, que necessitavam de uma avaliação mais precisa da alteração anatômica, nos quais foi feita a prototipagem tridimensional.

Resultados: O paciente 1 foi tratado conservadoramente e aguarda artroplastia da cabeça umeral caso haja pioria dos sintomas. O paciente 2 foi submetido a osteotomia valgizante do úmero proximal, fixada com placa bloqueada de quadril pediátrica conforme avaliação prévia da prototipagem. O paciente 3 foi submetido a desinserção do manguito e plastia dos tubérculos e posterior reinserção do manguito rotador. O paciente 4 foi submetido a ressecção artroscópica do degrau articular, capsulotomia 360 graus e tenólise do subescapular. O paciente 5 foi submetido a artroplastia reversa de ombro com enxerto ósseo em L na glenoide posterossuperior.

Conclusão: A prototipagem rápida em resina acrílica permite um melhor planejamento pré-operatório no tratamento das deformidades ósseas no ombro, minimiza o risco de intercorrências intraoperatórias, numa tentativa de aprimorar os resultados.

Introduction

The shoulder is the joint with the greatest range of motion of the human body and, in order to function properly, it is imperative that all articular and periarticular structures are in anatomical positions.[1–6] Bone anatomy plays a fundamental role because it is the basis for the origin and insertion of all other tissues, such as cartilage, labrum, ligaments, muscles, and tendons. Changes in the bone structure cause a biomechanical imbalance, with alterations in joint congruence as well as in muscle length and angulation, leading to shoulder girdle dysfunction.[4]

Bone deformities at the proximal end of the humerus can be traumatic (fractures) or degenerative (arthrosis). For the adequate treatment of these deformities, it is important to have a clear understanding of the anatomical changes through imaging tests. Simple radiography is limited, as it only provides a two-dimensional image.[7] Computed tomography with three-dimensional reconstructions allow a more detailed evaluation of the bone anatomy, but still presents limitations, such as limited accuracy and magnification of the exam; moreover, it does not allow the manipulation of the studied structure.[8,9]

Rapid prototyping is a method that makes real three-dimensional models based on virtual three-dimensional models.[10,11] It uses synthetic models to produce an accurate three-dimensional copy of the bone anatomy. This technique was developed in the 1980s and was initially used for industrial purposes and for detailed reconstructions of complex sculptures.[8] In the healthcare area, it is known as Medical Rapid Prototyping (MRP) and is most commonly used in oral and maxillofacial surgeries and neurosurgeries.[12] The first prototyping reconstructions were used for oral and maxillofacial reconstructions in the early 1990s; they began to be used in orthopedic surgeries at the end of that decade.[13] Nowadays, the biomedical use of prototyping already represents approximately 10% of the total market for the use of this technology, especially in oral and maxillofacial reconstruction and neurological surgeries;[11,13] it has even been used in the preparation of guides for placing screws that were planned preoperatively.[14,15]

In orthopedics, prototyping can be used from the treatment of fractures and malunion to the planning of orthopedic ortheses.[13,9,16,17] The technique has two stages: virtual (three-dimensional image) and physical (model manufacture). Initially, a computerized image of the structure to be studied is made; subsequently, the physical model is then manufactured by using computer-aided design (CAD) through the deposition of synthetic material.[10,11,18,19]

With the aid of the synthetic models produced through the prototyping technique, the surgeon can make a precise preoperative plan[9,20] by performing the technique on the prototype before the actual surgery or even by using the prototype in the intraoperative period, since the three-dimensional models produced from polyamide can be autoclaved.[21]

In this study, the authors describe five clinical cases in which the prototyping technique was used to study bone deformities of the shoulder. The goal is to promote and provide orthopedic surgeons with a more efficient and affordable method of surgical planning.