CADCAM Arch Bars: A Technical Note

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Abstract

Study Design: Technical note.

Objective: Computer-aided design and computer-aided manufacturing (CADCAM) is commonly used in craniomaxillofacial (CMF) surgery because of its advantage in customizing medical devices. We used this technology to create individualized, resin-bonded 3-dimensionally printed titanium arch bars.

Method: This article describes a patient specific, three-dimensionally (3D) printed, resin-bonded arch bar as an alternative to the classical intermaxillary fixation systems.

Results: The ease of application and removal, as well as the protection of the periodontal and cheek tissues, and operator fingers, made this a comfortable technique for both the patient and practitioner.

Conclusions: A patient-specific 3D-printed titanium arch bar can be useful in the arsenal of the maxillofacial surgeon.

Keywords

computer-aided design, computer-aided manufacturing, jaw fixation techniques, printing, 3-dimensional

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Introduction

Arch bars are widely used in craniomaxillofacial (CMF) surgery to position and immobilize bone segments containing dentition in reconstructive jaw surgery (e.g., posttraumatic, oncological, congenital, orthognathic, total temporomandibular joint [TMJ] replacement), while correcting malocclusion if present.

We aimed to introduce the concept of a custom-made, 3-dimensionally (3D) printed, resin-bonded arch bar as an alternative to circumdental wiring techniques and intermaxillary fixation screws when orthodontic appliances are absent.

Materials and Methods

Technique

An intra-oral scan of the dental arches was performed (3Shape Trios 3; 3Shape A/S, Copenhagen, Denmark). The .stl files were implemented into Geomagic Freeform Plus (3D Systems, Rock Hill, SC, USA) by CADskills BV (Sint-Denijs-Westrem, Ghent, Belgium) for the design of the arch bars according to the specific indication: monomaxillary for bilateral cleft alveolar bone grafting and bimaxillary for TMJ reconstruction or orthognathic surgery. The design of the arch bars comprised a rod (diameter 1.5 mm) and connecting square window frames (3 × 3 mm) containing 1 mullion and 1 transom. The windows, which are comparable with classic orthodontic brackets in both size and shape, were centered on the buccal surfaces of the teeth (Figure 1). The window is placed in the middle of the tooth when possible, but when necessary (deep occlusion), it is cervically translated in order to avoid interferences. To allow easier application of the resin adhesive, the internal cross was substituted with a single diagonal beam.

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(Figures 1 and 2). The external surface could be unpolished (Figure 1) or polished (Figure 2).

According to their purpose, the arch bars were designed with or without hooks for rigid and elastic intermaxillary fixation and with or without provisions to contain “TMJ exercisers.” These exercisers could be used to train and regain lateral mandibular movements by varying the training protocol with different exercises using rubber bands with variable elasticities. The hooks are designed in such a manner that the wires and elastics are kept away from the soft tissues.1

The arch bar is designed in Geomagic® Sculpt™ (3D Systems, Rock Hill, US) since there is no specialized software but the actual concept is company property and according to international regulations. The learning curve is moderate: for a monomaxillary arch bar, 2 hours are

Figure 1. Initial design of the window frames-unpolished, 1 mullion and 1 transom; modified design-single diagonal beam.

Figure 2. Modified arch bar design-polished, single diagonal beam (rendering and intra-oral placement).
needed to design it. If an additional exerciser is required, extra time is added. Including printing and processing, approximately 10 hours of manual labor are needed. Delivery time normally stays within 1 week.

The patient-specific arch bars were additively manufactured using selective laser melting (SLM) in Ti6Al4V Grade 23 ELI. Because this production method causes high stresses in these thin devices, they had to undergo a specific heat treatment to prevent deformations or even fractures. To optimize their surface roughness and resin retention, they were micropeened using an alumina grit (Ø = 550 μm) and etched for 10 minutes using 2 wt% oxalic acid at 85°C.

The manufacturing costs are depending on the case and may differ between countries. The arch bars were fixed to the dentition using a resin-bonded technique (35% phosphoric etching gel, Gel-Etch®, Temrex and flowable composite Tetric EvoFlow®; Ivoclar Vivadent). After 6 weeks, they were removed in the outpatient clinic by simple torquing. The buccal surfaces were afterwards polished in a dental office.

Examples

We demonstrate the technique for stabilization of the premaxilla in an alveolar bone grafting procedure in a bilateral cleft patient (Figure 3) and for maxillomandibular positioning during an alloplastic TMJ replacement procedure (Figure 4).

Results

The ease of application and removal (in our clinic the junior trainee places and removes the arch bar), the lack of pain and pressure on the tooth and surrounding tissues, as well as the protection of the periodontal and cheek tissues, and operator fingers, made this a comfortable technique for both the patient and practitioner.

In cases of TMJ replacement, the presence of integrated hooks facilitated postoperative physiotherapy. The TMJ exercisers helped lateral movements, both active and passive. The indications are currently bimaxillary advancement surgery for obstructive sleep apnea, TMJ replacement surgery, and premaxilla stabilization after alveolar bone grafting.

Discussion

The most common method for mandibulomaxillary fixation is arch bars, wire fixation (Ernst ligatures, Ivy loops, etc.) and bone supported devices. Arch bars are highly used in trauma cases because of availability, reliability and cost-effectiveness but the stainless steel circumdental wires, used to fix any type of arch bar, present some drawbacks including difficulty in maintaining good oral hygiene, associated periodontal problems, prolonged time for application and potential wire stick injuries. In addition,
the aforementioned techniques cannot be used in patients with extensive crown and bridge work. As an alternative, intermaxillary fixation screws and other hybrid systems were developed (e.g., Universal SMARTLock hybrid system; Stryker Corporation, Kalamazoo, MI). Recent studies have suggested that the damage to the tooth roots and soft tissue overgrowth on the screw heads make these systems far from ideal.\textsuperscript{3,4} Furthermore, a high rate of loosening or displacement of screws (29\%) occurs over time, compromising stability.\textsuperscript{5}

The idea of a patient specific 3D printed arch bar started with cleft patients. In most cases a repositioning osteotomy is needed so careful surgical preparation is required. Stabilization of the premaxillary segment in Veau IV cleft patients after alveolar bone grafting can be an onerous task. The mobility of the premaxillary segment endangers the blood supply, jeopardizing graft integration.\textsuperscript{6} Several methods have been reported for fixation of the premaxilla after a simultaneous corrective osteotomy.\textsuperscript{7,9} The most widely used method includes an occlusal splint fabricated before the surgery. Occlusal splints are held in place using orthodontic wire (0.3-mm stainless steel) and bone screws.\textsuperscript{7,10} This method has the advantage of reducing occlusal forces applied on the premaxilla during function. However, the penetration of labial mucosa and periosteum overlying the repositioned segment by bone screws can interfere with the blood supply, leading to improper healing and necrosis. Moreover, oral hygiene is difficult, leading to graft contamination and resorption.\textsuperscript{7} To overcome these disadvantages, Oyama et al\textsuperscript{8} proposed using glass ionomer cements for splint fixation.

A rigid method of stabilization is represented by internal plate fixation.\textsuperscript{11} In the mixed dentition period, internal fixation is not recommended because of the increased risk for tooth germ damage. The fixation of the premaxilla with brackets and orthodontic wire may be another option, but they have proven to be too resilient.\textsuperscript{7} Moreover, in most cases, the number of anchorage teeth is insufficient because of the loss of deciduous teeth and incomplete root formation of permanent teeth.\textsuperscript{11}

To combat the aforementioned disadvantages, we propose a periodontium-friendly alternative to the classical bent stainless steel arch bar: a patient-specific Ti6Al4V Gr 23 ELI 3D printed arch bar, supplying rigidity, biocompatibility,\textsuperscript{12} and comfort.

In the beginning we used the Unitek adhesive paste (3M™ United States)—capsules and dispenser, but the diameter of the tip of the capsules was too big to slide between the mullion and transom. Moreover, the lack of fluidity made the placement difficult and time consuming. So, we do recommend the flowable resin.

The arch bar sustains traction forces (e.g. intermaxillary fixation around the hooks) but it’s more sensitive for rotation forces around the rod. It did happen that during extubating, the patient had bitten directly onto the oral tube which got stuck into the cleft region in direct contact with the arch bar. As a consequence, the arch bar came loose.
From our experience it is the distal molar window the one that gets mostly loose. If that happens during the surgery, it is easily reattached if the operatory field is dry. Otherwise, we recommend a temporary circumdental wire until suture and hemostasis.

After using it with success in cleft patients, we decided to broaden its applicability in orthognathic and temporomandibular joint replacement patients.

Due to the compulsory designing time we do not use this arch bar in trauma cases.

**Conclusion**

The use of a patient-specific 3D-printed titanium arch bar can be helpful for specific indications such as: surgery-first or surgery-only orthognathic cases, alveolar grafting in bilateral cleft patients, temporomandibular joint replacement cases.

**Declaration of Conflicting Interests**

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Maurice Y. Mommaerts declares that he is an innovation manager at CADskills BV. Stijn E. F. Huys declares that he is an R&D and QARA manager at CADskills BV.

**Ethical Approval**

All the procedures in studies involving human participants were performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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**Informed Consent**

Informed consent was obtained from all the participants included in the study.

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