Design and Manufacture of Patient-specific Cobalt-Chrome Alloy Surgical Jigs for High Tibial Osteotomy Surgery

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Introduction

High Tibial Osteotomy (HTO) surgery is widely used as the treatment for early osteoarthritis. However, the surgical execution could be challenging as the surgery usually requires accurate cutting operations. Patient-specific instrument like 3D-printed surgical jigs can be helpful as they can provide guidance for cutting and spacing procedures during HTO surgeries. Traditionally, the jigs are printed by plastics and are thus easy to be deformed and melted. In this study, Cobalt-Chrome Alloy was used to manufacture rigid patient-specific surgical jigs for HTO surgeries.

Methods

Design and Manufacture Process of Patient-specific Cobalt-Chrome Alloy Surgical Jigs

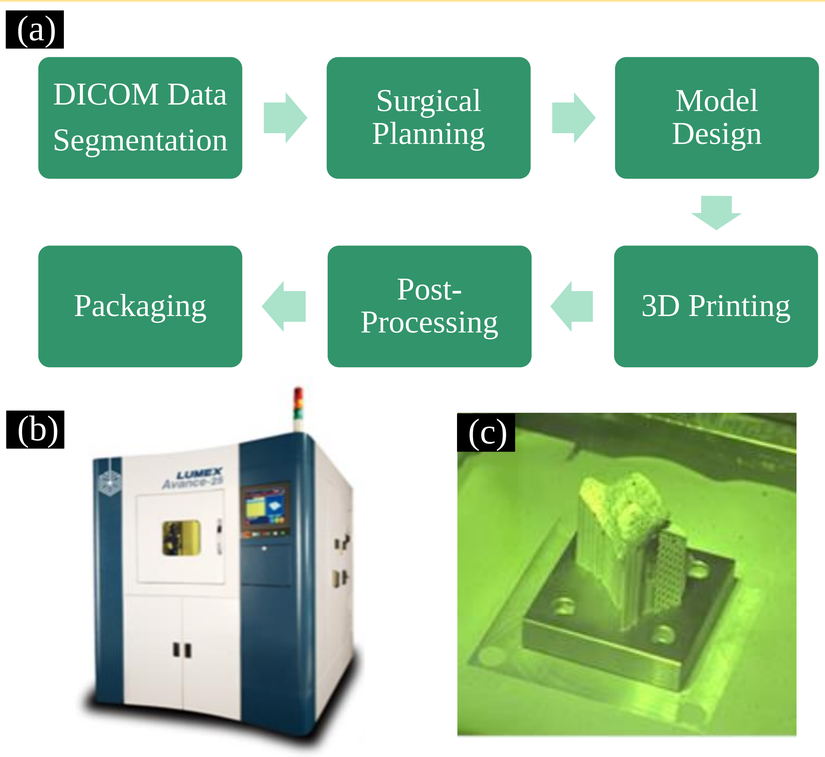

Fig.1. Design and manufacture of HTO surgical jigs: (a) Workflow of the production of patient-specific surgical jigs by additive manufacturing; (b) The Masuura LUMEX Avance-25 printer used in manufacture process; (c) 3D-printed jig before post-processing.

A streamlined workflow of the production of HTO surgical jigs (Fig.1a) often starts with the obtain and segmentation of pre-operative DICOM data, followed by surgical planning with collaborating surgeons. Based on the finalized plan, the 3D models of the HTO jigs are designed and sintered in a Matsuura Avance-25 metal 3D printer (Fig.1b&c) and then post-processed to remove supports and polish surface. ASTM F75 grade Co-28Cr-6Mo alloy metal powder were used for the 3D printing process.

Conclusions

The design and manufacture of patient-specific HTO surgical jigs were summarized. For various surgical conditions, different types of surgical jigs can be produced by additive manufacturing to meet clinical requirements. Manufactured jig shows positive effects in the clinical application. This study has demonstrated the feasibility and benefits to produce patient-specific surgical jigs by additive manufacturing for HTO surgeries.

Results and Discussion

Design of Different Types of HTO Jigs

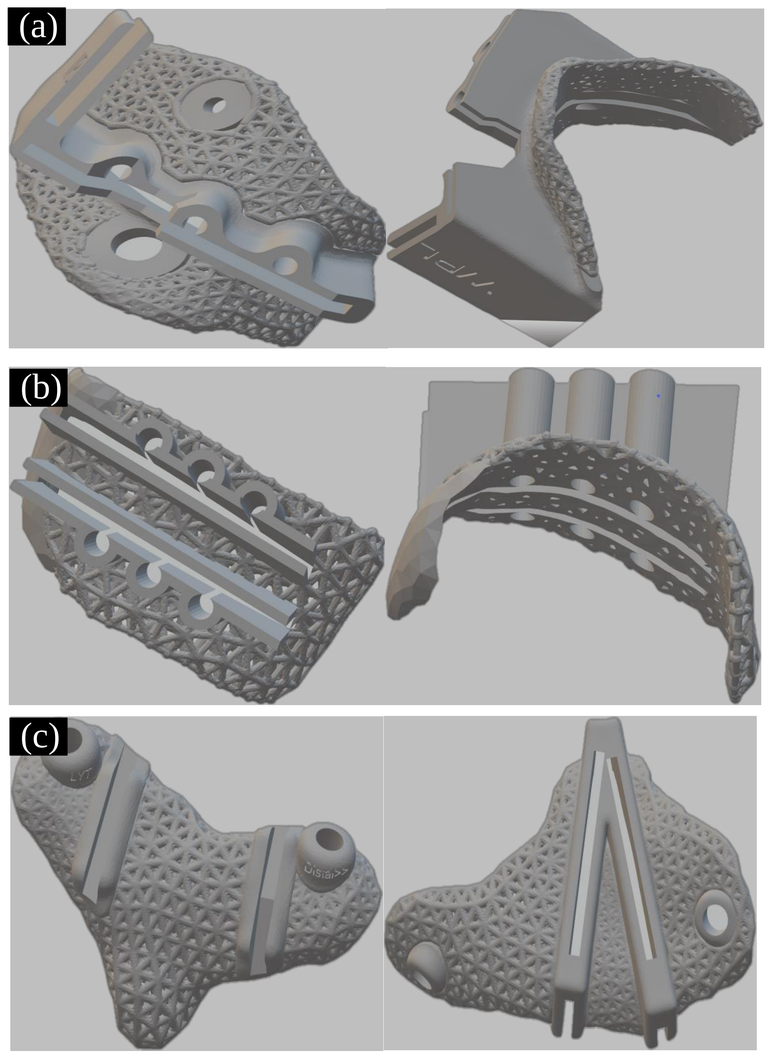

Fig.2. 3D model of different types of HTO jigs: (a) Open wedge surgical jig; (b) Closed wedge surgical jig; (c) Complex surgical jigs.

Three categories of HTO surgical jigs are shown in Fig.2. Fig.2(a) and (b) show the two families that are characterized by the open/closed wedge nature of the surgery in question, signifying that a simple realignment component will be required to assist in orthopaedic correction. For surgeries require complicated realignment process, complex surgical jigs (Fig.2(c)) will be designed for extensive realignment solutions. Complex surgical jig solution will include multiple cutting jigs in a single surgery.

Final Products of HTO Surgical Jigs

Fig.3. Finished HTO surgical jig product after post-processing(a) shows customized cutting guides and k-wire guides. 3D anatomical model could be used to verify the surface compliance of 3D-printed HTO surgical jigs with patient anatomy (b).

The main features of the HTO Surgical Jig are threefold; (a) surface compliant with patient anatomy based on patient CT scans, (b) cutting guide(s) based on preoperative planning data from surgeons and (c) k-wire/ cortical screw guides based on preoperative realignment data. Fig.3(a) shows the appearance of a final product of HTO surgical jig after support removal and surface polishing with clear cutting guides and k-wire guides. Fig.3(b) shows a common approach for the verification of the patient-specific surface of HTO surgical jigs using 3D-printed anatomical model.

High Tibial Osteotomy Surgery Using Patient-specific Surgical Jigs

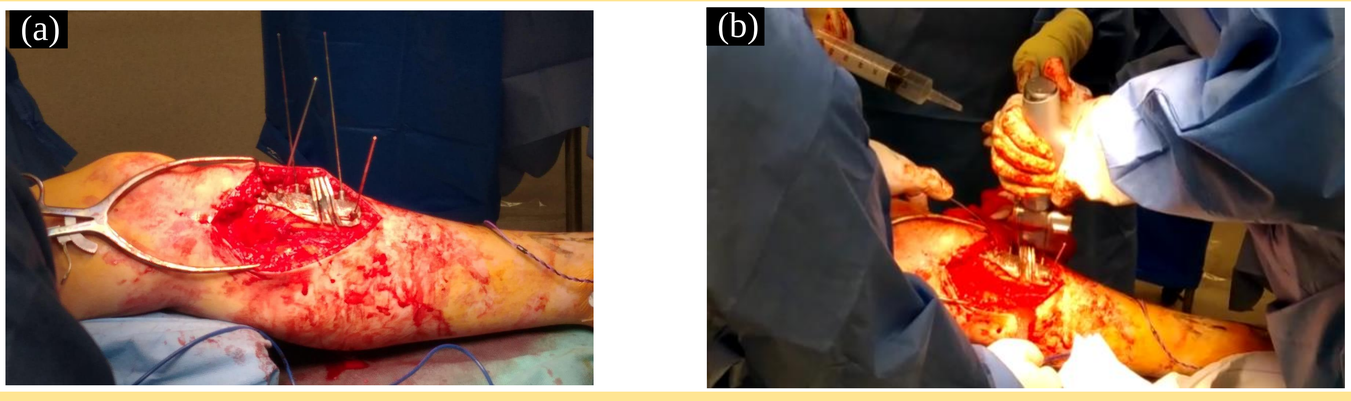

Fig.4. A high tibial osteotomy surgery case using the patient-specific surgical jig: (a)HTO surgical jig secured by k-wires; (b) Osteotomy with oscillating saw guided by the secured jig.

Fig.4 shows a high tibial osteotomy surgery in Queen Elizabeth Hospital (Hong Kong) in 2021 using our jig. After the jig secured by k-wires (Fig.4(a)), the surgeon could perform the osteotomy using an oscillating saw. With the guidance provided by the jig, the surgeon finished the cutting in less than one minute and achieve satisfactory clinical results. Unlike plastic guides, Cobalt-Chrome alloy surgical jigs do not have obvious deformation and potential debris, thus can provide safer and more accurate surgical guidance.

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