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TECHNICAL NOTE

Implant Removal Matrix for the upper Extremity Orthopedic Surgeon

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Abstract

Orthopedic implant removal is a commonly performed procedure. While implant removal can be associated with improved symptoms, risks of the surgery are notable. Stripped screws, broken and retained hardware, and morbidity associated with soft tissue compromise during difficult removal are all common. Familiarity with the instruments is critical to procedure success. The purpose of this study is to assist removal of unfamiliar screws in upper extremity surgery by offering a reference for screw and driver compatibility across manufacturers.

Inclusion of device manufacturers was determined by market share. Screw size, drive configuration, and screw removal system compatibility data was collected and recorded. Screw, guide-wire, and screwdriver compatibility was assessed and compared to two commonly utilized universal implant-removal sets.

Eight upper extremity implant vendors were included. The data was compiled in table format according to manufacturer and sub-categorized to facilitate screw identification according to radiographically identifiable characteristics.

The diversity of orthopaedic implants in upper extremity surgery requires careful preoperative planning to identify the appropriate equipment for implant removal.

The goal of this work is to provide a centralized reference of commonly implanted screws, guide-wires, and drivers for the upper extremity to facilitate removal.

Level of evidence: V

Keywords: Hardware complication, Hardware removal, Implant removal, Screw removal

Introduction

Orthopaedic implant removal is a common procedure with 10-15% of upper extremity fractures repaired requiring implant removal following plate osteosynthesis (1-5). Frequent reasons for implant removal include pain, tendon irritation or rupture, infection, nonunion, and hardware prominence (2, 5). While patients who undergo implant removal often have improvement in their symptoms, the ease of specific implant removal can vary considerably. In fact, 85% of surgeons report that implant removal poses a significant burden on hospital resources (3, 6-8).

The perceived burden of implant removal is not without cause, as it represents a considerable cost to both the patient and healthcare system (9). Implant removal surgeries are associated with a high frequency of complications, ranging from 12 to 41%, and can be associated with longer operative times and higher amounts of blood loss than initial procedures (10-13). Potential complications including general operative risks such as infection, bleeding, and injury to important structures are compounded by risks specific to removal of the implant itself, such as broken and/or retained hardware, stripped screws, and re-fracture during, or after implant removal (14, 15).

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Pre-operative knowledge of the instruments needed to remove a given implant is critical to minimize potential risk to the patient. Ideally, the initial treating orthopaedic surgeon would also remove the implants, as is frequently the case. However, patients change providers, leave prior areas of care, or present to other institutions with peri-prosthetic fractures, infections, or other implant complications requiring urgent removal. It is therefore critical for the treating surgeon to know the compatibility of the screw removal system with the previously implanted hardware. Furthermore, despite acquisition of a detailed prior operative report, there may still be ambiguity with respect to driver size and configuration as this may not be specifically enumerated in the operative report.

To assist surgeons removing unfamiliar instrumentation, several major orthopaedic implant companies have begun compiling universal extraction sets that take advantage of implant and driver compatibility amongst companies and simplify the extraction process (16, 17). While helpful, these removal sets do not include a compatibility reference and require direct visualization of the screw head to guide driver selection. These constraints make implant removal difficult, and necessitate intraoperative determination of implant and removal-set compatibility without the ability to plan instrument needs pre-operatively.

The purpose of this study is to facilitate removal of upper extremity specific orthopaedic implants by compiling a reference detailing the compatibility of screws produced by the most commonly used upper extremity orthopaedic implant companies with regard to two commonly used implant removal sets and generally available driver configurations (18).

Surgical technique

This study did not require Institutional Review Board (IRB) approval given criteria met for exempt status and no involvement of human or animal subjects. Orthopaedic implant manufacturer inclusion was determined by market share based upon industry-monitoring financial firms (17). Publicly available surgical technique guides, typically in portable document format (PDF), were retrieved for each manufacturer of plate osteosynthesis implants for the phalanges, metacarpals, scaphoid, distal radius, forearm, olecranon, and humerus. Intramedullary or arthroplasty implant sets were excluded. Each technique guide was thoroughly reviewed for implant and screwdriver information and, in some cases, surgical representatives were contacted to clarify the screw size and screw drive configuration, along with known removal set compatibility options. Screw and screwdriver compatibility were assessed and compared to two commonly utilized universal screw-removal sets as determined by the two highest grossing orthopaedic implant companies, Johnson & Johnson (J&J)/Depuy/Synthes (Raynham, MA) and Stryker (Kalamazoo, MI) (19). The data was compiled in table format with non-cannulated, locking, and cannulated screw offerings for each included company. Guide-wire size compatibility for cannulated offerings were also assessed and documented.

The top nine highest grossing upper extremity implant companies in 2017 according to market share were J&J/Depuy/Synthes with 31.5% of the market share, Zimmer/Biomet 23%, Wright Medical 10.5%, Stryker 8.4%, Smith & Nephew 4.2%, Exactech 4%, DJO 3.6%, Integra 0.8%, and Arthrex 0.2%.18 DJO medical does not produce osteosynthesis implants and accordingly was excluded from this analysis. In total, eight upper extremity implant companies with commonly implanted upper extremity screws were included in this review.

The following tables are divided into company-specific, noncannulated, cannulated, and locking screws; they are further organized by screw diameter, screw type, guidewire diameter (if cannulated), driver type, the driver's catalog number, and the universal removal set where the required driver can be found. If the manufacturer of the implant is known, the surgeon can use Table 1 to find the relevant removal information grouped by manufacturer. If the manufacturer is unknown, the surgeon can use a calibrated radiograph to identify and measure the screws and refer to Table 2 (noncannulated, nonlocking screws), Table 3 (cannulated screws), or Table 4 (locking screws). These tables are arranged by screw diameter and contain all associated extraction information for easy reference.

With proper preoperative planning, a surgeon can use these tables to determine which of the commonly available implant removal sets contains the necessary driver for a successful implant removal. While almost all the screws described in the tables can be removed by either the Synthes and/or the Stryker implant removal kits, there are a few screws that have non-traditional drive types. If the table indicates the necessary driver is not available in either removal set, then the catalog number of the driver produced by the manufacturer is provided. These catalog numbers are provided for all screws listed in the chart to allow surgeons to opt for a single driver if that option is available at their institution.

Discussion

The proliferation of orthopaedic implant designs has allowed fixation to be tailored to specific injury patterns and greater options for orthopaedic surgeons. However, this diversity of implants is also problematic when implanted hardware requires removal especially when the operating surgeon did not perform the index procedure. Complications following implant removal for upper extremity fractures can be as high as 40%.15 Selection of the appropriate driver is paramount to the success and expediency of an implant removal surgery. Indeed, it has been shown that a single slippage event can halve the maximal torque tolerated by a screw and hamper screw removal (20).

The data reported in this study was prepared in an effort to facilitate appropriate driver selection for

Table 1. Screws Organized By Vender

J&J/Depuy/Synthes				
Screw Diameter	**Screw Type**	**Driver Type/Size**	**Catalog Number**	**Removal Set**
1.0mm	Cortex, self-tapping	Cruciform 1.0mm	314.48.96	Synthes
1.3mm	Cortex, self-tapping	Cruciform 1.3mm	314.411.96	
1.5mm	Cortex, locking Cortex, self-tapping Locking cortex, self-tapping	Hexalobular T4 Cruciform 1.5/2.0mm	03.114.009 314.67.96	
1.8mm	Buttress Pin	Hexalobular T8	314.467	Synthes/Stryker
2.0mm	Cortex, self-tapping Cortex, self-tapping Locking Cortex, self-tapping	Cruciform 1.5/2.0mm Hexalobular T6 Cruciform 2.4mm	314.67.96 313.843 313.94.96	Synthes
2.4mm	Cannulated, headless compression (1.1mm) Cortex, self-tapping Locking	Hexalobular T8	314.467	Synthes/Stryker
2.7mm	Cortex, self-tapping compression Cortical NL Locking	Hex 2.5 mm Hexalobular T8	314.10 314.467	
3.0mm	Cannulated (1.1 mm) Cannulated, headless compression (1.1mm)	Cruciform 4.0 mm Hexalobular T8	314.463 314.467	Not Available Synthes/Stryker
3.5mm	Cannulated (1.25 mm) Cortical NL Cortical NL Locking Locking	Hex 2.5 mm Hexalobular T15 Hex 2.5 mm HexalobularT15	314.290 314.116 314.030 314.116	
4.0 mm	Cancellous Locking Cortex, self-tapping Cannulated (1.25 mm)	Hex 2.5 mm Hexalobular T25 Hex 2.5 mm	314.03 03.019.020 314.290	
6.5 mm	Cannulated (2.8 mm)	Hex 4.0 mm	314.050	
7.0 mm	Cannulated (2.0mm)	Hex 3.5 mm	314.190	
7.3 mm	Cannulated (2.8 mm)	Hex 4.0 mm	314.050	
Zimmer/Biomet				
Screw Diameter	**Screw Type**	**Driver Type/Size**	**Catalog Number**	**Removal Set**
1.3 mm	Cortical NL	Cruciform 1.3mm	2312-20-208	Synthes
1.5mm	Locking Cortical NL	Square 1.5mm	2312-20-209	Not Available

Table 1. Continued

1.8 mm	Locking Peg	Hexalobular T8	00-236-010-00	Synthes/Stryker
2.0 mm	Locking Peg	Hex 2.5 mm	231211001	
2.2 mm	Locking	1.7/2.2 mm square	2312-00-101	Not Available
2.4 mm	Locking Cortical NL	Hexalobular T8	00-236-010-00	Synthes/Stryker
2.5mm	Locking	Square 2.5mm	2312-20-205	Not Available
	Locking Cortical NL	Square 1.3mm	2312-18-012	
	Cortical NL MDTP	Square 2.5mm	2312-20-205	
	Cannulated (.9mm)	Hex 1.5mm	231201225	Synthes
	Partially threaded Peg, Locking Peg screw, NL	Hex 2.5 mm	231211001	Synthes/Stryker
2.7 mm	Cortical NL	1.7/2.2 mm square	2312-00-101	Not Available
	Cortical NL Conical	Hex 2.5 mm	00-2360-175-20	Synthes/Stryker
	Locking	1.7/2.2 mm square	2312-00-101	Not Available
3.2 mm	Locking Peg	Hexalobular T15	11017562	Synthes/Stryker
3.4 mm	cannulated (1.1 mm)	2.0 mm Hex	231201230	Not Available
3.5 mm	Locking	1.7/2.2 mm square	2312-00-101	
	Locking Cortical NL	Hex 2.5 mm	00-2360-175-20 231211001	
	Cortical NL MDS Cortical, Locking	Hexalobular T15	11017562	Synthes/Stryker
4.0 mm	Cannulated (3.2mm) Cancellous	Hex 2.5 mm	231201240	
	Locking Cancellous	Hexalobular T15	11017562	
Stryker				
Screw Diameter	**Screw Type**	**Driver Type/Size**	**Catalog Number**	**Removal Set**
1.2 mm	Cortical NL	Cruciform 1.2 mm	62-12335	
1.4 mm	Cortical NL		62-12335	Not Available
2.0 mm	Locking Peg	Hexalobular T7	62-27015	
	Cannulated (0.8mm)	Hexalobular T6		Synthes
2.3 mm	Locking	Hexalobular T7	62-27015	Not Available
	Cortical NL	Cruciform 2.4mm		Synthes
	Cortical NL	Hexalobular T7	62-27015	Not Available

Table 1. Continued

2.5 mm	Headless compression	Hex 1.5 mm		Synthes
	Cortical NL	Hexalobular T10	45-3015	
2.7 mm	Locking Locking Peg Cortical NL	Hexalobular T7	62-27015	Not Avail[a]ble
	Cortical NL Locking	Hexalobular T10	45-3015	Synthes
3.0 mm	Locking Cannulated (1.2mm)	Hexalobular T8	702759	Synthes/Stryker
3.5 mm	Cortical NL Locking	Hexalobular T10	45-3015	Not Available
	Headless compression	Hex 2.0 mm		
4.0 mm	Cannulated (1.4 mm)	Hex 2.5 mm	702382	Synthes/Stryker
	Locking	Hexalobular T15	702747	
	Cannulated (1.4 mm)	Hex 2.5 mm	702382	
	Headless compression	Hexalobular T15	702747	
5.0 mm	Cannulated (2 mm)	Hex 3.5 mm	702480	
	Locking	Hexalobular T20	702748	Stryker
6.5 mm	Cannulated (3.2 mm)	Hex 5.0 mm	702629	Synthes/Stryker
Wright Medical				
Screw Diameter	**Screw Type**	**Driver Type/Size**	**Catalog Number**	**Removal Set**
1.5 mm	Cortical NL	Hexalobular T6	49510100	Synthes
2.0 mm	Cortical NL Polyaxial Locking Locking	Hexalobular T7	49510102	Not Available
	Cannulated (0.9mm)	Hexalobular T8	49510100	Synthes/Stryker
2.5 mm	Cannulated (0.9mm)			
	Cannulated (0.9mm)	Hex 1.5mm		Synthes
2.7 mm	Locking Cortical NL	Hexalobular T10	49510055	Not Available
	Locking Cortical NL	Hexalobular T15 Hex 2.5 mm	58861T15	Synthes/Stryker
3.0 mm	Cannulated (1.1mm)	Hexalobular T10	49510055	Not Available
	Cannulated (1.0mm)	Hex 2.0 mm	4112001	
3.3 mm	Cortical NL	Hex 2.5 mm		Synthes/Stryker
3.5 mm	Locking Cortical NL Cannulated (1.1mm) Locking Cancellous	Hexalobular T10	49510055	Not Available
	Locking Cortical NL	Hexalobular T15	58861T15	Synthes/Stryker
	Cancellous	Hexalobular T10	49510055	Not Available

Table 1. Continued

4.0 mm	Cannulated (1.4mm) Cortical NL	Hexalobular T15	58861T15	Synthes/Stryker
4.3 mm	Cannulated (1.6mm)	Hex 3.0 mm	44112007	Not Available
5.0 mm	Cortical NL	Hexalobular T20	MWJ123	Stryker
Smith & Nephew				
Screw Diameter	**Screw Type**	**Driver Type/Size**	**Catalog Number**	**Removal Set**
1.5 mm	Locking Cortical NL	Hexalobular T4	7446-1504	Synthes
1.8 mm	Locking peg	Hexalobular T7	7117-4927	Not Available
2.0 mm	Locking peg Locking Cortical NL	Hexalobular T6	7117-4921	Synthes
2.4 mm	Cortical NL Locking	Hexalobular T7	7117-4927	Not Available
2.5 mm	Cortical NL	Hex 1.5 mm	7117-0036	Synthes
2.7 mm	Cortical NL Locking	Hex 2.5 mm	7117-3585	Synthes/Stryker
	Cortical NL Locking	Hexalobular T8	7117-4933	
	Cortical NL Locking	Hexalobular T15	7117-3614	
3.0 mm	Cancellous Osteopenia	Hexalobular T7	7117-4927	Not Available
3.5 mm	Cortical NL	Hexalobular T20	7117-3592	Stryker
	Cortical NL	Hex 3.5mm	7117-3488	Synthes/Stryker
	Cortical NL	Hexalobular T15	7117-3614	
	Locking	Hexalobular T20	7117-3592	Stryker
	Locking	Hex 3.5mm	7117-3537	
	Locking	Hexalobular T15	7117-3614	Synthes/Stryker
4.0 mm	Fully threaded osteopenia screw	Hexalobular T8	7117-4933	
	Cancellous	Hexalobular T20	7117-3592	Stryker
	Cannulated (1.3mm)	Hex 2.5 mm	7117-3585	
4.5 mm	Cortical NL Locking	Hexalobular T25	7117-3616	Synthes/Stryker
5.7 mm	Cortical NL Cannulated (2.0mm)	Hex 3.5mm	7117-3537	
Exactech				
Screw Diameter	**Screw Type**	**Driver Type/Size**	**Catalog Number**	**Removal Set**
3.8 mm	Compression	Hexalobular T10	341-01-38	Not Available
3.8 mm	Locking			
4.5 mm	Locking	Hex 3.5 mm	321-15-08	Synthes/Stryker
6.5 mm	Locking	Hexalobular T25	341-01-65	

Table 1. Continued

Integra				
Screw Diameter	**Screw Type**	**Driver Type/Size**	**Catalog Number**	**Removal Set**
2.4 mm	Cortical NL	Hex 2.5 mm	60-0724	Synthes/Stryker
	Locking	Hexalobular T7	303408	Not Available
2.7 mm	Locking	Hexalobular T8	5010010	
2.8 mm	Cortical NL	Hex 2.5 mm	26-8700	Synthes/Stryker
	Cortical NL			
	Locking	Hex 2.0 mm	302310	Not Available
3.5 mm	Locking	Hexalobular T15	5010009	
	Cortical NL			
4.5 mm	Cortical NL	Hex 2.5 mm	26-8700	Synthes/Stryker
	Cortical NL			
4.5 mm	Locking	Hexalobular T15	348094	
5.5 mm	Compression	Hexalobular T25		
Arthrex				
Screw Diameter	**Screw Type**	**Driver Type/Size**	**Catalog Number**	**Removal Set**
2.0 mm	Cannulated (0.86 mm)	Hexalobular T8	AR-8610D-30	Synthes/Stryker
	Cortical NL			
2.4 mm	Cannulated (0.86 mm)			
	Locking			
2.5 mm	Cortex FT	Hex 1.5 mm	AR-8714D	Synthes
	Fragment Screw	Hexalobular T8	AR-8610D-30	Synthes/Stryker
	Headless Cannulated (1.0 mm)	Hexalobular T7	AR-8610D-25	Not Available
2.7 mm	Cortex NL	Hexalobular T10	AR-8737-38	
	Locking			
3.0 mm	Cortex FT			
	Cannulated (1.1 mm)			
	Headless Cannulated (1.0 mm)	Hexalobular T8	AR-8610D-30	
3.5 mm	Cortical NL	Hex 2.5 mm	AR-14025	Synthes/Stryker
	Cannulated (1.2 mm)			
	Locking Hexalobular T15	AR-8943-12		
	Cortical NL	Hexalobular T10	AR-8737-38	Not Available
4.0 mm	Cannulated (1.35 mm)	Hexalobular T15	AR-8943-12	Synthes/Stryker
	Jones Screw	Hexalobular T8	AR-8610D-30	
	Locking	Hex 2.5 mm	AR-14025	
	Cannulated PT (1.6 mm)	Hex 3.5 mm	AR-8967D	
4.5 mm	Jones Screw	Hexalobular T8	AR-8610D-30	
	Cortical NL	Hexalobular T20	AR-13223C	Stryker
	Locking			
5.5 mm	Cortical NL			
	Jones Screw	Hexalobular T8	AR-8610D-30	Synthes/Stryker
6.7 mm	Cannulated PT (2.4 mm)	Hex 3.5 mm	AR-8967D	

Table 2. Noncannulated and Nonlocking Screws

Screw Diameter	Manufacturer	Screw Type	Driver Type/Size	Manufacturer Driver	Recommended Removal Set
1.0mm	J&J/Depuy/Synthes	Cortex, self-tapping	Cruciform 1.0mm	314.48.96	Synthes
1.2 mm	Stryker	Cortical NL	Cruciform 1.2 mm	62-12335	Not Available
1.3 mm	Zimmer/Biomet	Cortical NL	Cruciform 1.3mm	2312-20-208	Synthes
	J&J/Depuy/Synthes	Cortex, self-tapping		314.411.96	
1.4 mm	Stryker	Cortical NL	Cruciform 1.2 mm	62-12335	Not Available
1.5mm	J&J/Depuy/Synthes	Cortex, locking	Hexalobular T4	03.114.009	Synthes
	J&J/Depuy/Synthes	Cortex, self-tapping		03.114.009	
	J&J/Depuy/Synthes	cortex, self-tapping	Cruciform 1.5/2.0mm	314.67.96	
	Smith & Nephew	Cortical NL	Hexalobular T4	7446-1504	
	Zimmer/Biomet	Cortical NL	Square 1.5mm	2312-20-209	Not Available
	Wright Medical	Cortical NL	Hexalobular T6	49510100	Synthes
1.8 mm	J&J/Depuy/Synthes	Buttress Pin	Hexalobular T8	314.467	Synthes/Stryker
1.9mm	Smith & Nephew	Cortex NL	Cruciform 1.7mm	62-17335	**Not Available**
2.0mm	J&J/Depuy/Synthes	Cortex, self-tapping	Cruciform 1.5/2.0mm	314.67.96	Synthes
	Smith & Nephew	Cortex NL	Hexalobular T6	7117-4921	
	J&J/Depuy/Synthes	Cortex, self-tapping		313.843	
	Wright Medical	Cortical NL	Hexalobular T7	49510102	Not Available
2.3 mm	Stryker	Cortical NL	Cruciform 2.4mm		Synthes
	Stryker	Cortical NL	Hexalobular T7	62-27015	Not Available
2.4mm	J&J/Depuy/Synthes	Cortex, self-tapping	Cruciform 2.4mm	313.94.96	Synthes
	J&J/Depuy/Synthes	Cortex, self-tapping	Hexalobular T8	314.467	Synthes/Stryker
	Integra	Cortical NL	Hex 2.5 mm	60-0724	
	Smith & Nephew	Cortical NL	Hexalobular T7	7117-4927	Not Available
	Arthrex	Cortical NL	Hexalobular T8	AR-8610d-30	Synthes/Stryker
2.5 mm	Zimmer/Biomet	Cortical NL	Square 1.3mm	2312-18-012	Not Available
	Zimmer/Biomet	Cortical NL	Square 2.5mm	2312-20-205	
	Arthrex	Cortical NL	Hex 1.5 mm	AR-8714D	Synthes
	Stryker	Cortical NL	Cruciform 2.4 mm	62-23335	
2.7mm	J&J/Depuy/Synthes	Cortex, self-tapping	Hexalobular T8	314.467	Synthes/Stryker
	J&J/Depuy/Synthes	compression	Hex 2.5 mm	314.10	
	J&J/Depuy/Synthes	Cortical NL			
	Stryker	Cortical NL	Hexalobular T10	45-3015	Not Available
	Stryker	Cortical NL	Hexalobular T7	62-27015	
	Smith & Nephew	Cortical NL	Hex 2.5 mm	7117-3585	
	Smith & Nephew	Cortical NL	Hexalobular T8	7117-4933	Synthes/Stryker
	Smith & Nephew	Cortical NL	Hexalobular T15	7117-3614	
	Zimmer/Biomet	Cortical NL	1.7/2.2 mm square	2312-00-101	Not Available
	Zimmer/Biomet	Cortical NL	Hex 2.5 mm	00-2360-175-20	Synthes/Stryker
	Zimmer/Biomet	Conical			
	Wright Medical	Cortical NL	Hexalobular T10	49510055	Not Available
	Wright Medical	Cortical NL	Hex 2.5 mm		Synthes/Stryker
	Integra	Cortical NL		26-8700	
3.0 mm	Arthrex	Cortical NL	Hexalobular T10	AR-8737-38	Not Available
	Arthrex	Cortical NL			
	Smith & Nephew	Cancellous Osteopenia	Hexalobular T7	7117-4927	

Table 2. Continued

3.3 mm	Wright Medical	cortical NL	Hex 2.5 mm		
	J&J/Depuy/Synthes	Cortical NL	Hexalobular T15	314.116	Synthes/Stryker
	J&J/Depuy/Synthes	Cortical NL	Hex 2.5 mm	314.030	
3.5mm	Stryker	Cortical NL	Hexalobular T10	45-3015	Not Available
	Zimmer/Biomet	Cortical NL	Hex 2.5 mm	231211001	Synthes/Stryker
	Zimmer/Biomet	Cortical NL	Hexalobular T15	11017562	
	Smith & Nephew	Cortical NL	Hexalobular T20	7117-3592	Stryker
	Smith & Nephew	Cortical NL	Hex 3.5mm	7117-3488	Synthes/Stryker
	Smith & Nephew	Cortical NL	Hexalobular T15	7117-3614	
	Wright Medical	Cortical NL	Hexalobular T10	49510055	Not Available
	Wright Medical	Cortical NL	Hexalobular T15	58861T15	Synthes/Stryker
	Wright Medical	Cancellous	Hexalobular T10	49510055	Not Available
	Integra	Cortical NL	Hexalobular T15	5010009	Synthes/Stryker
	Integra	Cortical NL	Hex 2.5 mm	26-8700	
	Arthrex	Cortical NL	Hexalobular T10	AR-8737-38	Not Available
4.0 mm	Arthrex	Cortical NL	Hex 2.5 mm	AR-14025	Synthes/Stryker
	J&J/Depuy/Synthes	Cancellous		314.03	
	J&J/Depuy/Synthes	Cortex, self-tapping			
	Zimmer/Biomet	Cancellous		00-2360-175-20	
	Smith & Nephew	Fully threaded osteopenia screw	Hexalobular T8	7117-4933	
	Smith & Nephew	Cancellous	Hexalobular T20	7117-3592	Stryker
	Wright Medical	Cortical NL	Hexalobular T15	58861T15	
4.5 mm	Smith & Nephew	Cortical NL	Hexalobular T25	7117-3616	Synthes/Stryker
	Smith & Nephew	Cortical NL	Hex 3.5mm	7117-3537	
	Arthrex	Cortical NL	Hexalobular T20	AR-13223C	Stryker
	Integra	Cortical NL	Hex 2.5 mm	26-8700	Synthes/Stryker
5.0 mm	Wright Medical	Cortical NL	Hexalobular T20	MWJ123	Stryker
5.5 mm	Integra	Compression	Hexalobular T25		Synthes/Stryker
	Arthrex	Cortical NL	Hexalobular T20	AR-13223C	Stryker

Table 3. Cannulated Screws

Screw Diameter	Manufacturer	Screw Type	Guidewire	Driver Type/Size	Manufacturer Driver	Removal Set
2.0 mm	Arthrex	Cannulated	0.86 mm	Hexalobular T8	AR-8610D-30	Synthes/Stryker
	Stryker	Compression	0.8 mm	Hexalobular T6		Synthes
2.4 mm	Wright Medical	Compression	0.9 mm	Hexalobular T8	49510100	Synthes/Stryker
	DePuySynthes	Compression	1.1mm		314.467	
	Arthrex	Cannulated	0.86 mm		AR-8610D-30	
2.5 mm	Zimmer Biomet	Compression	0.9 mm	Hex 1.5 mm	231201225	Synthes
	Wright Medical	Compression	0.9 mm	Hexalobular T8	49510100	Synthes/Stryker
	Wright Medical	Compression	0.9 mm	Hex 1.5 mm		Synthes
	Arthrex	Headless compression	1.0 mm	Hexalobular T7	AR-8610D-25	Not Available

Table 3. Continued

3.0 mm	DePuySynthes	Compression	1.1 mm	Hexalobular T8	314.467	Synthes/Stryker
	DePuySynthes	Cannulated	1.1 mm	Cruciform 4.0 mm	314.463	Not Available
	Wright Medical	Compression	1.1 mm	Hexalobular T10		
	Wright Medical	Compression	1.0 mm	Hex 2.0 mm	4112001	
	Arthrex	Cannulated	1.1 mm	Hexalobular T10	AR-8737-38	
	Arthrex	Headless compression	1.0 mm	Hexalobular T8	AR-8610D-30	Synthes/Stryker
3.4 mm	Zimmer Biomet	Compression	1.1 mm	Hex 2.0 mm	231201230	Not Available
3.5 mm	Arthrex	Cannulated	1.2 mm	Hex 2.5 mm	AR-14025	Synthes/Stryker
	DePuySynthes	Cannulated	1.25 mm		314.290	
	Wright Medical	Compression	1.1 mm	Hexalobular T10		Not Available
4.0 mm	DePuySynthes	Cannulated	1.25 mm	Hex 2.5 mm	314.290	Synthes/Stryker
	Arthrex	Cannulated	1.6 mm	Hex 3.5 mm	AR-8967D	
	Wright Medical	Compression	1.4 mm	Hexalobular T15		
	Zimmer Biomet	Compression	3.2 mm		231201240	
	Stryker	Compression	1.4 mm	Hex 2.5 mm	702382	
	Stryker	Cannulated	1.4 mm			
	Smith and Nephew	Compression	1.3 mm		7117-3585	
4.3 mm	Wright Medical	Cannulated	1.6 mm	Hex 3.0 mm	44112007	Not Available
5.7 mm	Smith and Nephew	Compression	2.0 mm	Hex 3.5mm	7117-3537	Synthes/Stryker
6.5 mm	Stryker	Cannulated	3.2 mm	Hex 5.0 mm	702629	Stryker
6.7 mm	DePuySynthes	Cannulated	2.8 mm	Hex 4.0 mm	314.050	Synthes/Stryker
	Arthrex	Cannulated	2.4 mm	Hex 3.5 mm	AR-8967D	
7.0 mm	DePuySynthes	Cannulated	2.0 mm	Hex 3.5 mm	314.190	
7.3 mm	DePuySynthes	Cannulated	2.8 mm	Hex 4.0 mm	314.050	

Table 4. Locking Screws

Screw Diameter	Manufacturer	Specialty Screw	Driver Type/Size	Manufacturer Driver	Removal Set
1.5 mm	DePuySynthes	Locking	Hexalobular T4	03.114.009	Synthes
	Zimmer/Biomet	Locking	Square 1.5mm	2312-20-209	Not Available
	Smith&Nephew	Locking	Hexalobular T4	7446-1504	Synthes
1.8 mm	Zimmer/Biomet	Locking Peg	Hexalobular T8	00-236-010-00	Synthes/Stryker
	Smith&Nephew	Locking peg	Hexalobular T7	7117-4927	Not Available
2.0 mm	DePuySynthes	locking	Hexalobular T6	313.843	Synthes
	Zimmer/Biomet	Locking Peg	Hex 2.5 mm	231211001	Synthes/Stryker
	Stryker	Locking Peg	Hexalobular T7	62-27015	Not Available
	Smith&Nephew	Locking peg	Hexalobular T6	7117-4921	Synthes
	Wright Medical	Polyaxial locking	Hexalobular T7	49510102	Not Available
	Wright Medical	Locking			
2.3 mm	Stryker	Locking		62-27015	
	Stryker	Locking	Cruciform 2.4mm	62-23335	Synthes

Table 4. Continued

2.4 mm	DePuySynthes	Locking	Hexalobular T8	314.467	Synthes/Stryker
	Zimmer/Biomet	Locking		00-236-010-00	
	Smith&Nephew	Locking	Hexalobular T7	7117-4927	Not Available
	Arthrex	locking	Hexalobular T8	AR-8610D-30	Synthes/Stryker
2.5 mm	Zimmer/Biomet	Locking	Square 2.5mm	2312-20-205	Not Available
	Zimmer/Biomet	Locking	Square 1.3mm	2312-18-012	
	Zimmer/Biomet	MDTP	Square 2.5mm	2312-20-205	
	Zimmer/Biomet	Partially threaded Peg, Locking	Hex 2.5 mm	231211001	
2.7 mm	DePuySynthes	Locking	Hexalobular T8	314.467	Synthes/Stryker
	Zimmer/Biomet	Locking	Hex 2.5 mm	00-2360-175-20	
	Zimmer/Biomet	Locking	1.7/2.2 mm square	2312-00-101	Not Available
	Stryker	Locking	Hexalobular T7	62-27015	
	Stryker	Locking Peg			
	Stryker	Locking	Hexalobular T10	45-3015	
	Smith&Nephew	Locking	Hex 2.5 mm	7117-3585	Synthes/Stryker
	Smith&Nephew	Locking	Hexalobular T8	7117-4933	
	Smith&Nephew	Locking	Hexalobular T15	7117-3614	
	Wright Medical	Locking	Hexalobular T10	49510055	Not Available
	Wright Medical	Locking	Hexalobular T15	58861T15	Synthes/Stryker
	Integra	Locking	Hexalobular T7	303408	Not Available
	Integra	Locking	Hexalobular T8	5010010	Synthes/Stryker
	Arthrex	Locking	Hexalobular T10	AR-8737-38	Not Available
3.0 mm 3.2 mm	Stryker	Locking	Hexalobular T8	702759	Synthes/Stryker
	Zimmer/Biomet	Locking Peg	Hexalobular T15	11017562	
	DePuySynthes	Locking	Hex 2.5 mm	314.030	
	DePuySynthes	Locking	Hexalobular T15	314.116	
3.5 mm	Zimmer/Biomet	Locking	1.7/2.2 mm square	2312-00-101	Not Available
	Zimmer/Biomet	Locking	Hex 2.5 mm	00-2360-175-20	Synthes/Stryker
	Zimmer/Biomet	Cortical, Locking	Hexalobular T15	2142-15-070	
	Stryker	Locking	Hexalobular T10	45-3015	Not Available
	Smith&Nephew	Locking	Hexalobular T20	7117-3592	Stryker
	Smith&Nephew	Locking	Hex 3.5 mm	7117-3537	Synthes/Stryker
	Smith&Nephew	Locking	Hexalobular T15	7117-3614	
	Wright Medical	Locking	Hexalobular T10	49510055	Not Available
	Wright Medical	Locking	Hexalobular T15	58861T15	Synthes/Stryker
	Integra	Locking	Hex 2.0 mm	302310	Not Available
	Integra	Locking	Hexalobular T15	5010009	Synthes/Stryker
	Arthrex	Locking	Hex 2.5 mm	AR-14025	
	Arthrex	Locking	Hexalobular T15	AR-8943-12	

Table 4. Continued

3.8 mm	Exactech	Locking	Hexalobular T10	341-01-38	Not Available
4.0 mm	DePuySynthes	Locking	Hexalobular T25	03.019.020	Synthes/Stryker
	Zimmer/Biomet	Locking Cancellous	Hexalobular T15	11017562	
	Stryker	Locking		702747	
	Arthrex	Locking	Hex 2.5 mm	AR-14025	
4.5 mm	Smith&Nephew	Locking	Hexalobular T25	7117-3616	
	Exactech	Locking	Hex 3.5 mm	321-15-08	
	Integra	Locking	Hexalobular T15	348094	
5.0 mm	Arthrex	Locking	Hexalobular T20	AR-13223C	Stryker
	Stryker	Locking		702748	
6.5 mm	Exactech	Locking	Hexalobular T25	341-01-65	Synthes/Stryker

removal of upper extremity orthopaedic implants. One potential benefit of this data is reduced hospital cost. Operating room (OR) cost ranges from $22 to $133 per minute, not including surgeon and anesthesiologist time (21, 22). Improved OR efficiency through appropriate driver selection pre-operatively and expeditious surgery can represent a significant time and cost savings. More accurate instrument selection and avoided instrument tray reprocessing could yield further savings, ranging from $75 to $330 per instrument set not used (23).

Limitations of this study include the lack of inclusion of all upper extremity orthopaedic companies in the overall analysis. Though data from industry monitoring financial firms was used to compile a list representing 82% of the market share for upper extremity orthopaedic implants, companies with a smaller market share were omitted due to logistical necessity (18). Additionally, although care was taken to ensure the accuracy of information collected for the reference, sample equipment was not available to perform physical verification with the implants themselves. Accordingly, the information presented in this manuscript is to serve as a guide and by no means a comprehensive or definitive source.

Future areas of study include the goal of identifying how readily this guide may be used to facilitate specific screw identification based upon a radiograph with magnification markers according to the proposed characteristics. It would further be beneficial to determine the distinct cost savings incurred through use of this guide with regard to both operative time and reprocessing costs.

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