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RESEARCH AND EDUCATION

In vitro comparison of the efficacy of two fractured implant-prosthesis screw extraction methods: Conventional versus mechanical

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ABSTRACT

Statement of problem. Implant-supported prostheses may be subject to esthetic, biological, or mechanical complications. Protocols for dealing with these mechanical problems are sparse.

Purpose. The purpose of this in vitro study was to compare the efficacy of a mechanical system for extracting fractured implant-prosthesis screws with the conventional method.

Material and methods. A total of 60 screws were divided into 2 groups according to their morphology (flat screws with a smooth shaft and threaded apical area and screws with a completely threaded body) and subjected to fatiguing and static load testing until fracture. The specimens were assigned to 3 operators with varying levels of clinical experience (high, medium, low) in extracting fractured screws by using the conventional method (explorer and ultrasound device) and a mechanical method (extractor kit). The extraction event (whether the screw fragment was extracted or not within 10 minutes) was recorded, and the time taken to perform the extraction was measured for each method in relation to screw type, operator experience, and damage to the threads. The influence of screw morphology, extraction method, operator experience, and fracture type on the time needed to extract a screw fragment was assessed with the Mann-Whitney and Kruskal-Wallis tests. Thread damage was compared by using the Fisher's exact test and the Kruskal-Wallis test (α=.05).

Results. The mechanical method was more effective for screw extraction than the conventional method (P=.032). Screw morphology also had a significant influence on extraction, whereby the screw design with apical thread took less time to extract (P=.022). Coronal fractures had a higher probability of extraction than apical fractures (P=.05).

Conclusions. Mechanical extraction is more effective for extracting fractured implant-prosthetic screws, showing a higher probability of extraction than the conventional method. Prosthetic fixing screws with a smooth shaft and threaded apical area are the easiest to extract. (J Prosthet Dent 2020;124:720-6)

Implant-supported prostheses may be subject to esthetic, biological, or mechanical complications. Correct diagnosis and adequate treatment planning are essential for minimizing this risk.[1-4] Fracture of the prosthetic fixing screw inside the implant has been reported as one of the most frequent complications,[5,6] with a rate between 0% and 10.4% in studies with 5-year follow-ups[5-7] and 29% with 20-year follow-up.[8] Screw fracture may occur as a result of inadequate torque, incorrect passive fit between the implant and prosthesis, excessive occlusal forces, or a cantilever design.[4,9-12] Higher rates of fracture have been reported in partial implant-supported prostheses than in complete-arch prostheses.[5,13-17]

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Clinical Implications

A mechanical method (extractor kit) for extracting fractured implant-prosthetic screw fragments is more effective than the conventional method of using an explorer and ultrasound device, as it is a more straightforward and faster that it does not require the acquisition of special clinical skills.

No universal method for extracting fractured screws has been established, and various techniques have been described in clinical reports, mostly involving the use of conventional dental instruments.[18,19] Research into mechanical systems for extracting fractured implant screws is sparse. The authors are aware of only 1 in vitro trial of 2 mechanical extractor kits compared with the conventional method, in which the extractor kits obtained better results for retrieving the fractured screw fragments.[17]

The purpose of the present study was to evaluate, in vitro, the efficacy of a mechanical method of extracting fractured implant-prosthetic screws. The hypotheses were that the mechanical extraction method would be more effective in terms of both the extraction event itself and the time taken to perform the extraction than the conventional method; that neither the conventional nor the mechanical method would damage the screw thread; that screw morphology would not influence the capacity for fractured screw fragment removal; and that the clinical experience of the operator responsible for extraction would influence his or her capability in screw fragment removal.

MATERIAL AND METHODS

The study used a sample of 60 grade IV titanium implants with an internal hexagonal connection, measuring 4.25 mm in diameter and 11.50 mm in length (Kohno; Sweden & Martina). The implants were fixed in nylon tubes with epoxy resin (Exakto-Form; bredent) angled at 30 degrees as in the International Standardization Organization protocol (ISO 14801)[20] for fatigue testing of endosseous implants with straight abutments. Sixty prefabricated grade IV titanium abutments (Echo Chairside; Sweden & Martina) were screwed onto the implants with 2 types of screws with 1.25-mm-diameter hexagonal heads. These prosthetic fixing screws had 2 morphologies: Type A, a titanium screw with a smooth shaft and threaded apical section (N=30) (Fig. 1A); Type B: a titanium screw with a completely threaded body (N=30) (Fig. 1B). The abutment-screw complex was screwed onto the implant by applying a 30-Ncm torque by using a dynamometric torque wrench (Sweden & Martina) according to the manufacturer's instructions.

The assembly was fatigued in a dynamic load machine (Chewing Simulator CS-4.2; SD Mechatronik GmbH) that simulated mastication; the specimens were cyclic loaded for 60 000 cycles at a frequency of 2 Hz and an 80-N load. All specimens then underwent static loading in a universal test machine with a 5000-N load (Autograph AGX-V; Shimadzu) and a crosshead speed of 0.5 mm/min until the screw fractured.[21] A single experienced clinician (M.B.-L.) examined all the specimens under an optical microscope at ×40 magnification (M80; Leica Microsystems) to determine the depth at which fracture had occurred: in the coronal third, middle third, or apical third. In case of doubt, a second experienced clinician (R.A.-P.) was consulted to classify fracture location.

After screw fracture, the specimens were distributed between 3 operators with varying clinical experience of implant-supported prostheses: a professor with extensive experience with implant-supported prostheses (high experience); a predoctoral dental student (low experience); and a postgraduate dental student (moderate experience). Each operator received 20 specimens, 10 of each type (Types A and B). The 10 specimens per group per operator were then divided into 2 groups according to the extraction method used. The distribution of specimens was randomized at every stage by means of an online randomization software program (www.alazar.info) (Table 1).

The test groups (mechanical extractor kit versus the conventional method with explorers and ultrasound device) were assigned to operators with high (A1 and B1), low (A2 and B2), and medium (A3 and B3) level of experience. An independent examiner (G.S.-V.) ensured that both screw extraction procedures were performed in the same way by all operators. The examiner collected all data: the extraction event (was the screw fragment retrieved or not?), the time taken for each extraction, and the satisfaction of each operator with the 2 procedures. A maximum time of 10 minutes was allotted for each extraction; if, at the end of 10 minutes, the screw fragment had not been removed, it was classified as not extracted. In addition, operator experience, fracture type, and damage to the screw thread were considered in the comparison between methods and operators.

Two methods of fractured screw fragment extraction were compared: conventional and mechanical. The conventional method involved extraction by means of standard instruments in clinical use (an explorer [Fig. 2A] and an ultrasound device [Fig. 2B]). For the mechanical method, an extractor kit was used (Broken Screw Extractor Kit; Rhein83). The kit comprised a claw reamer bur (Fig. 3A) designed to

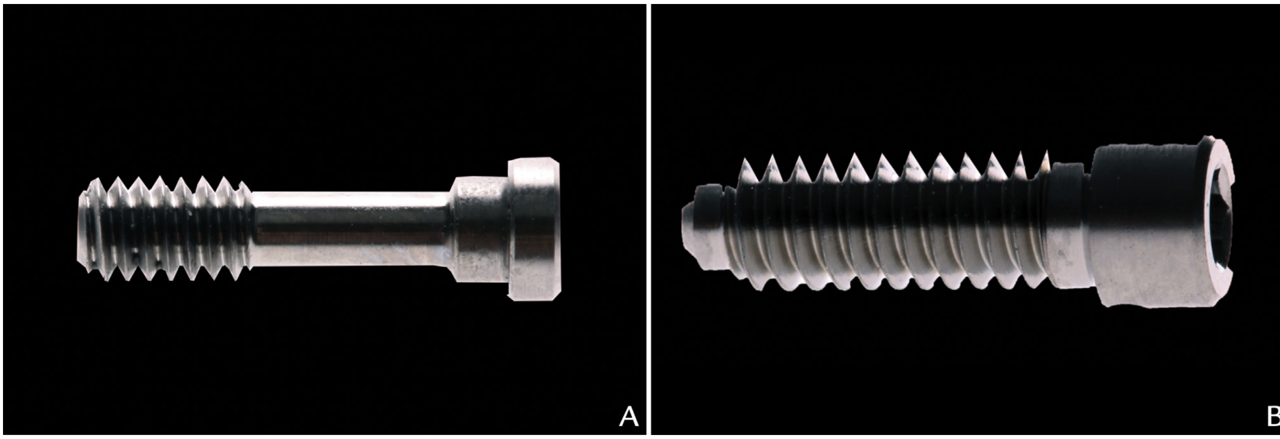

Figure 1. Fixing screws. A, Screw with smooth shaft and threaded apical part (Type A). B, Screw with completely threaded body (Type B).

Table 1. Distribution of groups and subgroups

Sample	Test Groups and Subgroups			
	Screw Type	Test Groups	Test Subgroups	Specimens Allotted (N°)
Specimens n=60	An n=30	Group A1 (operator 1) n=10	Subgroup A1.1 n=5 Conventional method	5,6,16,25,27
			Subgroup A1.2 n=5 Rhein83 method	19,10,14,29,17
		Group A2 (operator 2) n=10	Subgroup A2.1 n=5 Conventional method	7,4,18,3,12
			Subgroup A2.2 n=5 Rhein83 method	15,13,28,1,26
		Group A3 (operator 3) n=10	Subgroup A3.1 n=5 Conventional method	23,22,24,2,20
			Subgroup A3.2 n=5 Rhein83 method	30,9,11,8,21
	B n=30	Group B1 (operator 1) n=10	Subgroup B1.1 n=5 Conventional method	5,6,16,25,27
			Subgroup B1.2 n=5 Mechanical method	19,10,14,29,17
		Group B2 (operator 2) n=10	Subgroup B2.1 n=5 Conventional method	7,4,18,3,12
			Subgroup B2.2 n=5 Mechanical method	15,13,28,1,26
		Group B3 (operator 3) n=10	Subgroup B3.1 n=5 Conventional method	23,22,24,2,20
			Subgroup B3.2 n=5 Mechanical method	30,9,11,8,21

grasp the fractured screw fragment, notched to indicate the depth of the fragment's coronal part, and used to monitor the progress of the extraction and a centering device (Fig. 3B) used in combination with the claw reamer bur (Fig. 3C). First, the centering device was inserted manually, checking that its hexagonal connection fitted that of the implant so that it could be held in place firmly. Second, the claw reamer bur was inserted through the centering device until it contacted the fractured screw. A notch in the coronal tip of the claw reamer bur was designed to help it to engage with the screw fragment. The centering device was held firmly while the bur was inserted until it contacted the screw. Then, the bur was turned manually in a counterclockwise direction under constant pressure. After 4 turns, the notches on the bur emerged, indicating the exit of the bur and screw fragment into the centering device. Finally, the centering device and the bur holding the screw fragment were removed, or if the screw fragment remained inside the implant, it would be loose enough to be easily removed with cotton pliers. The claw reamer bur could also have been used in a contra-angle handpiece in a counterclockwise direction at a low speed (15-20 rpm) (Fig. 4).

Damage to the implants' internal thread after screw fragment removal was assessed by screwing a new screw identical to the extracted fractured screw into

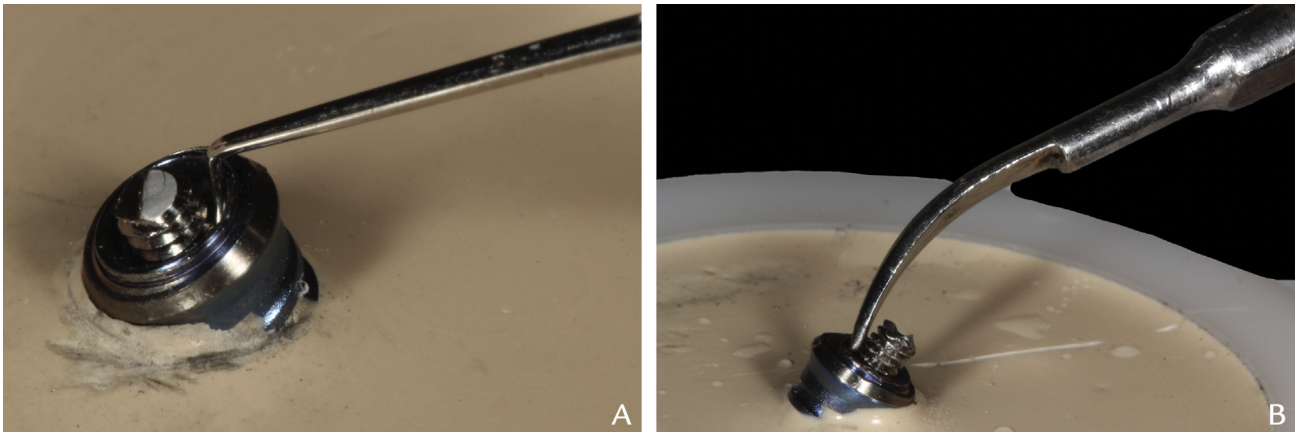

Figure 2. Conventional fractured screw extraction method. A, With explorer. B, With ultrasound device.

each implant and recording whether the screw could be inserted completely or not. To do this, a manual screwdriver (HSML-20-DG; Sweden & Martina) and a dynamometric wrench (CRI5-KIT; Sweden & Martina) applying 30-Ncm torque were used.[17]

The level of operator satisfaction, after the use of the 2 methods of extraction of screws (mechanical/conventional), was assessed through a survey by using the job satisfaction 0- to 10-point scale described by Warr et al (Table 2).[22] This questionnaire provided an objective assessment of satisfaction with the task performed.[16]

A statistical analysis was performed by using a specified statistical software program (IBM SPSS Statistics, v19.0; IBM Corp). Degrees of association between the extraction event and independent variables—screw type, fracture type, method, operator experience—were identified by using a simple binary logistic regression model and nonadjusted odds ratio (OR) estimation. To determine the influence of screw morphology, extraction method, operator experience, and fracture type on the time needed to extract a screw fragment, the Mann-Whitney and Kruskal-Wallis association tests were applied. Internal thread damage was compared between the independent variables by applying the Fisher's exact test and the Kruskal-Wallis test (α=.05).

RESULTS

Supplemental Table 1 (available online) shows the data collected: the outcome of the extraction event for each screw, extraction method, operator experience, the type of screw fracture, and analysis of each implant's internal thread. Of the 60 screws, 51 were extracted in less than 10 minutes, which represents a success rate of 85%. The mean time needed to extract screw fragments was 1.26 ±1.05 minutes. The conventional method had a success rate of 73.3% and the mechanical method 96.7%.

Type A screws had a higher extraction rate (93.93%) than Type B (76.7%). The simple binary logistic regression model and nonadjusted OR estimation showed that only the type of method (mechanical versus conventional) influenced extraction success significantly (*P*=.032), with the mechanical method being more effective, whereby the probability of successful extraction was 20 times higher with the mechanical method than with the conventional method. The influence of screw morphology was not significant (OR=0.240; *P*=.088).

No significant differences were found between operators with different levels of experience (*P*>.05); none had a higher level of ability with these techniques. As for the type of fracture, 91.4% of screws presenting coronal fracture, 82.4% of screws fractured in the middle third, and 62.5% of screws with apical fractures were extracted. Simple binary logistic regression models and nonadjusted OR estimation found significant differences only when apical and coronal factures were compared, with the probability of extraction being higher when the fracture was coronal (*P*=.05) (Fig. 5).

The mean time taken to extract the fractured screw fragments was 1.26 ±1.05 minutes. The mean extraction time was 2.44 minutes with the conventional method and 1.20 minutes with the mechanical method. The Mann-Whitney and Kruskal-Wallis tests showed that the type of screw was the only factor that significantly influenced the extraction time (*P*=.022), extraction being faster with Type A (mean time 1.22 minutes) than with Type B (mean time 2.42 minutes) (Fig. 6).

Damage to the implant's internal thread could only be assessed after a fractured screw had been successfully extracted, which occurred in 51 cases out of 60. Threads suffered damage in 4 implants (7.8%), but no significant

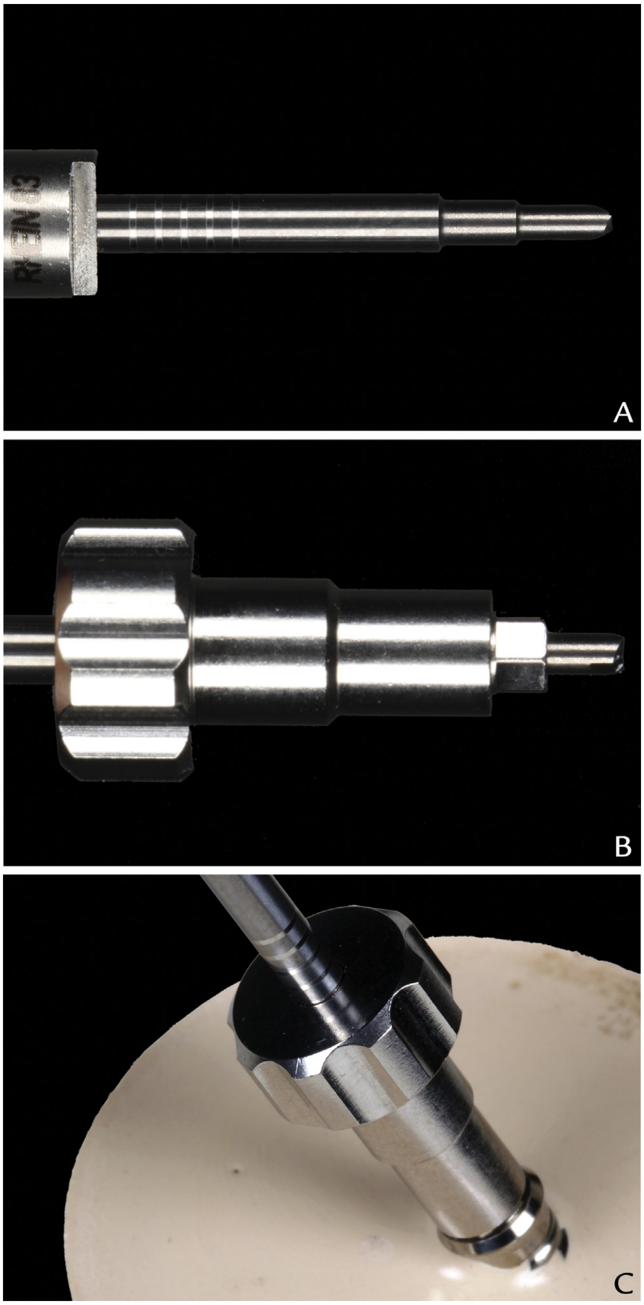

Figure 3. Mechanical extractor kit components. A, Claw reamer bur. B, Centering device with bur inserted. C, Claw reamer bur inserted through centering device fitted onto implant prosthetic platform.

relationship was found with methods or levels of operator experience (*P*>.05).

Regarding the satisfaction of the operators with the 2 methods, higher scores were awarded to the mechanical method than to the conventional method: ease of use (10 versus 6), time taken (8 versus 6.33), and advantage of clinical experience (10 versus 7). These specific items corresponded to the scores for general satisfaction, which reflected a preference

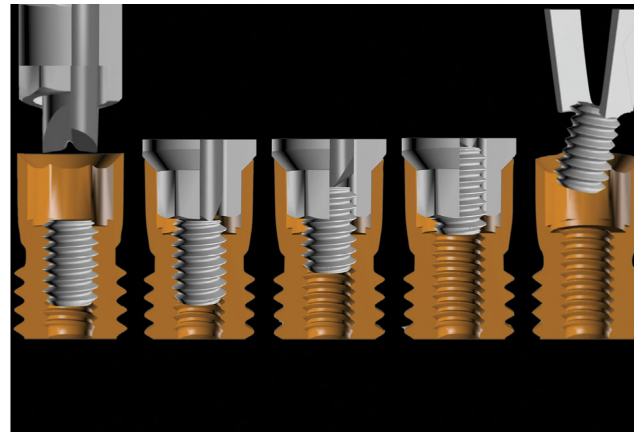

Figure 4. Mechanical method of fractured screw extraction by using the Rhein83 extractor kit; extraction protocol with claw reamer bur and centering device.

for the mechanical method (9.33 versus 6.44) (Table 3).

DISCUSSION

The results obtained supported the first hypothesis, as the mechanical method was more effective, showing a higher probability of successful fractured screw extraction than the conventional method. This finding may be because the extractor kit made it possible to unscrew the fractured fragment more easily and with greater stability than with an explorer and ultrasound device. However, when dealing with apical fractures with the mechanical system, the guide with the claw reamer bur will not reach the screw because of a stopper on the upper part of the centering device.[17] In this situation, extraction must be carried out without the centering device, taking care not to damage the internal threads of the implant.

Damage to the internal threads is a complication that may not be correctable, necessitating implant removal and replacement.[23] In the present study, the threads of 4 implants were found to have been damaged (3 with the mechanical method and 1 with the conventional method), a finding that led to the rejection of the second hypothesis that neither the conventional method nor the extraction device would damage the screw thread. No statistical difference was found between the method and the experience of the operator.

The third hypothesis was also rejected as screw morphology did influence extraction time significantly, Type A screws (smooth shaft with threaded apical part) being quicker to remove as this involved unscrewing less thread length than with Type B (completely threaded body). While screw morphology had no influence on the extraction event itself, it did influence the time needed for removal. The Type A design made

Table 2. Satisfaction survey according to extraction method

Items Evaluated	Not Assessable (0)	Completely Dissatisfied (1)	Very Dissatisfied (2)	Quite Dissatisfied (3)	Dissatisfied (4)	Neither Satisfied nor Dissatisfied (5)	Satisfied (6)	Quite Satisfied (7)	Very Satisfied (8)	Completely Satisfied (9)	Excellent (10)
Ease of use											
Time needed											
Independence from operator experience											
General satisfaction											

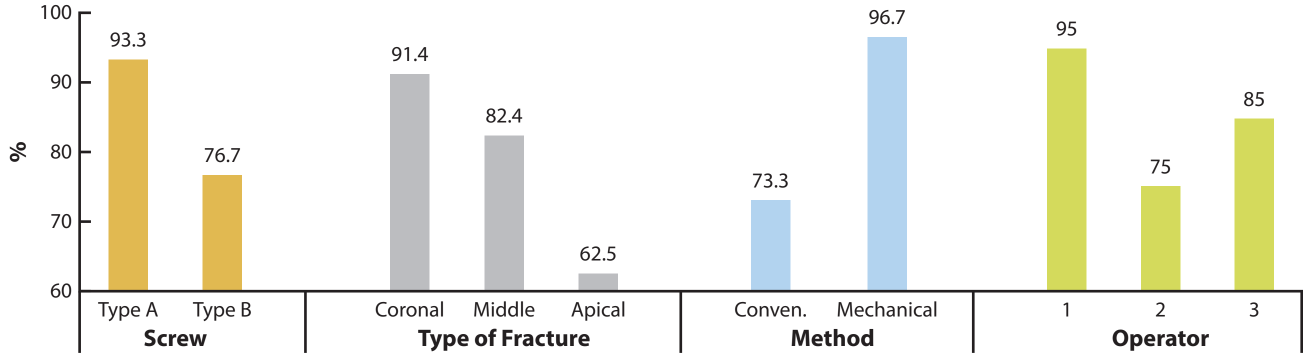

Figure 5. Extraction success rate in relation to variables analyzed: screw type, fracture type, method, and level of operator experience.

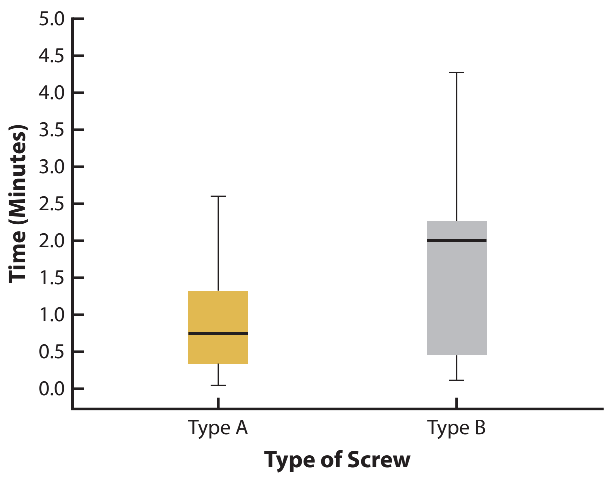

Figure 6. Box plot for extraction time for 2 screw types. *Red:* conventional method; *Orange:* mechanical method.

it possible to extract the screw more quickly. Clinician experience did not influence their capacity to remove fractured screw fragments, so the fourth hypothesis was also rejected.

The last hypothesis was confirmed, as the operators' satisfaction with the mechanical extractor kit was high, scoring 9.33 on the satisfaction scale. Operators considered manipulating the fractured screw fragment with an explorer and ultrasound device more complicated and awarded the method a mean score of 6.44, while using the extractor kit with a claw reamer bur and centering device ensured successful extraction in almost all situations. As for the time needed to remove the screw, the mechanical method was faster, and the operators were more satisfied with the extractor kit than with the conventional method in this respect. They also believed that successful extraction did not depend on operator experience, thanks to the ease of use of the extractor kit.

Establishing an effective protocol for extracting fractured screws is difficult, and few in vitro trials of fractured screw management have been published. As a result, there is little scientific evidence to help the clinician choose among methods. Moreover, the authors are unaware of research that investigated satisfaction with the different methods available, a factor that should be considered and which could have a bearing on the further development of extraction methods and even on their efficacy.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. The mechanical method was more effective for fractured screw extraction, obtaining a greater probability of successful extraction than the conventional method.
2. Extraction of screws with a smooth shaft and threaded apical part (Type A) and screws presenting coronal fractures involved more effective extraction, with statistically significant differences.

Table 3. Satisfaction scale items and points awarded (0-10)

Operator	1		2		3		Total	
Method	Conventional	Mechanical	Conventional	Mechanical	Conventional	Mechanical	Conventional	Mechanical
Ease of use	6	10	6	10	6	10	6	10
Time needed	6	9	7	8	6	8	6.33	8
Independence from operator experience	8	10	6	10	7	10	7	10
						General satisfaction	6.44	9.33

3. No significant differences between the methods were found based on the operator's level of experience.
4. Operators expressed a higher level of satisfaction with the mechanical method.
5. Further in vitro and clinical trials are needed to test the efficacy of the available screw extraction systems.

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