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Comparison of Lapidus procedure fixation methods for hallux valgus: a 10-year retrospective analysis

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ABSTRACT

Background: The purpose of this study was to identify the type of Lapidus fixation method used in Leeds Teaching Trust Hospital that produces the best post-operative radiographical measurements.
Methods: Thirty-five patients who underwent the Lapidus procedure were reviewed. Pre-operative and post-operative X-rays were measured to obtain angles; hallux valgus angle (HVA), first intermetatarsal angle (IMA), distal metatarsal articulate angle (DMA), meary angle (MA), and metatarsal declination angle (MDA). The fixation groups compared were dorso-medial plate vs dorsal plate vs medial plate and plate-single screw versus plate-crossed screw. The change in angle (Δ-angles) between pre-operative and post-operative were measured and the groups were compared. The fixation method that resulted in the largest Δ-angles and is statistically significant will be regarded as a superior fixation type within that group.
Results: Groups with plate-single screw fixation showed a statistically significant ($p<0.05$) larger change in distal metatarsal articulate angle compared to plate-crossed screw fixation. Dorso-medial plate showed largest Δ-angles in the plate group although none were statistically significant.
Conclusions: Fixation systems with single-screw result in better radiographical measurements compared to crossed-screws, significantly with the distal metatarsal articular angle. Dorso-medial plates result in better radiographical measurements followed by dorsal plate and then medial plate. However, these findings need validation with a randomized controlled trial before being generalized.

Keywords: Lapidus procedure, Halux valgus, Dorso-medial plate, Distal metatarsal articular angle

INTRODUCTION

The first ray is a segment of the foot that consists of the first metatarsal and first cuneiform bones. It serves several functions, particularly in maintaining the foot arch and energetics for locomotion. Due to this, pathologies that influence the first ray have deleterious consequences on a person's ability to walk. The most frequent pathology affecting the first ray is hallux valgus which is a lateral deviation of the 1st phalanx with medial deviation of the first metatarsal causing a bunion formation. Hallux valgus corrective procedures have been evolving for decades. The frequent technique used is to approach the deformity from the transverse plane where it is the most severe. Although this appeared to be the most logical, versions which are attentive to the sagittal and frontal plane have received a good reputation due to their success. This allowed for the deformity to be classified as a triplane deformity, and so allowed manipulation of a range of angles and lengths ensuing in lesser complications and better prognosis. The procedure that allows for triplane correction is arthrodesis of the first tarsometatarsal (TMT) joint or better known as the Lapidus procedure.[1]

The Lapidus procedure is a surgical technique which Paul W. Lapidus made popular in 1934, thus bearing his name.

It is a fusion of the first tarsometatarsal joint or better known as first TMT arthrodesis. It is indicated in Hallux valgus where there is hyper mobility of the first ray segment.

Arthrodesis can be performed using a variety of fixation techniques. The metalworks for TMT arthrodesis include plates and screws. Within these, there are variations in combinations, site, and stiffness. This vastness of surgical options available has led to the question of which method is the most effective, or if there even is a superior method. Lapidus arthrodesis with a plate and compression screw is an established procedure in hallux valgus surgery and biomechanical experiments show that plates in a plantar offer more benefit.[2,3]

In this retrospective study, radiographical results between different fixation methods were measured on pre-operative and post-operative X-rays. The angles measured in the first ray being the hallux valgus angle (HVA), intermetatarsal angle (IMA), distal metatarsal articular angle (DMA), Meary angle (MA), and metatarsal declination angle (MDA). This study aimed to assess the influence of different Lapidus methods on the angle outcomes. We hypothesized that feet with plantar plates and/or crossed screws will have the most favorable angle outcomes. The goal of the study is to measure the differences of change in angle among the fixation methods in the Lapidus Procedure and to identify the fixation method that produces the best radiographical measurements.

METHODS

Ethical approval

This study was exempted from ethical approval due to retrospective study design.

Study design

A retrospective review of patients who underwent the Lapidus procedure (LP) at Leeds Teaching Hospital Trust from the past 10 years (2012-2022) was done. Data was collected from the electronic patient records (EPR) software in LTHT called patient pathway manager (PPM+). It is clinical software that stores patient records and documents. Variables collected included, age, sex, operation notes and post-op complications. The patients' records collected were then anonymized using an online tool.

Inclusion criteria include patients who have both their pre-op and post-op X-rays and patients who have both antero-posterior and lateral views of the diseased foot. Exclusion criteria included feet that had undergone previous surgery prior to LP, post-operative complications such as non-union and infection which warranted the removal of metalwork and any other indication of LP other than hallux valgus.

Radiographic evaluation

The latest pre-op X–ray and the final post-op X-rays were used. Standard weightbearing AP and lateral view X-rays were uploaded to Xero viewer where we used the in-built measurement software to measure the pre-op and post-op following angles. Hallux valgus angle (HVA) defined as the angle in between the longitudinal axes of the 1st metatarsal bone and the proximal phalanx of the hallux. Intermetatarsal angle (IMA) is defined as angle between the longitudinal axes of the first and second metatarsals. Distal metatarsal articular angle (DMAA) is the angle between the longitudinal axis of the first metatarsal and another line parallel to the ground. Metatarsal declination angle (MDA) is defined as angle between the longitudinal axis of the first metatarsal and another line parallel to the ground. Meary angle (MA) is defines as angle of the point of intersection between the longitudinal angle of the first metatarsal and the longitudinal angle of the talus. The type of fixation was also noted. Two 5th year medical students who have both completed a training module to use Xero viewer took the angle measurements. Measurements were taken by both medical students separately. The difference in pre-operative and post-operative angles were then calculated by both students and the average value was used in analysis to minimize human error.

On plain radiography, the HVA is defined as the angle in between the longitudinal axes of the 1st metatarsal bone and the proximal phalanx of the hallux as shown by Figure 1. This angle has the most reproducible and acts as a measurement to assess the degree of severity of a bunion.[4] A normal HVA is less than 15 degrees and anything over that is divided into mild (15 degrees), moderate (20 degrees) and severe (40 degrees).[5]

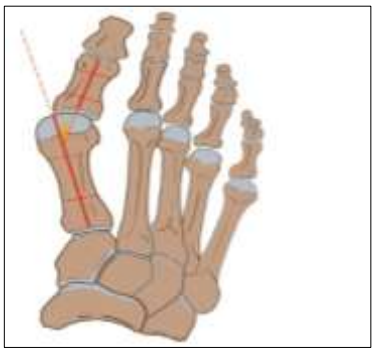

Figure 1: HVA.

The IMA is the angle formed between the 1st and 2nd metatarsal as highlighted in Figure 2. It is used alongside the HVA as it increases linearly with the HVA and correlates strongly with the severity of deformity.[6] An angle less than 9 is considered normal with >9, 11 and 18 representing mild, moderate and severe deformities.[7]

The DMA angle is the angle formed between the articular surface and the line perpendicular to the longitudinal axis

of the first metatarsal and estimates the congruence of the MTP joint seen in Figure 3.[8]

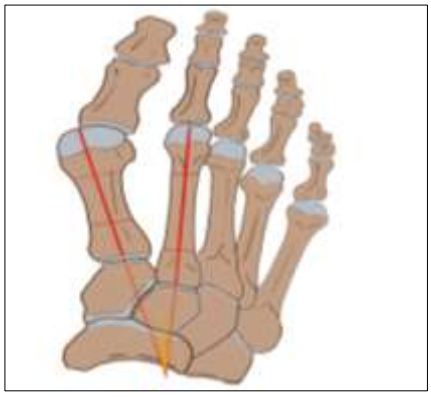

Figure 2: IMA.

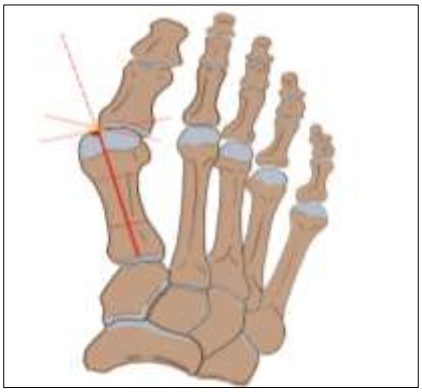

Figure 3: DMAA.

MDA is seen in literature as a radiographical assessment of hallux vallgus in the sagittal section.[9] It is the angle between the longitudinal axis of the first metatarsal and another line parallel to the ground demonstrated by Figure 4.

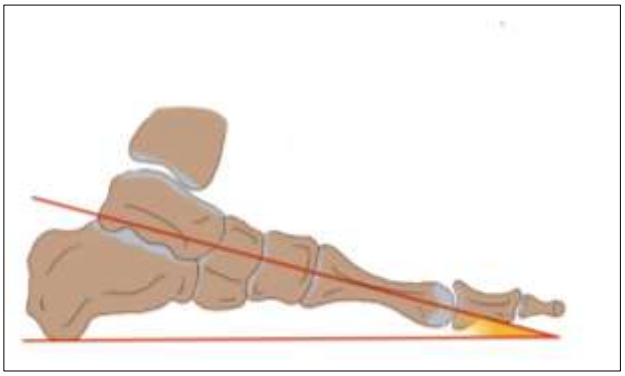

Figure 4: MDA.

The MA is the angle of the point of intersection between the longitudinal angle of the first metatarsal and the longitudinal angle of the talus as seen in Figure 5. If the point of crossing is located dorsally, the angle was positive and it was located plantarly, the angle was considered negative. Positive values indicate pes cavus while positive values indicate pleus planus.[9]

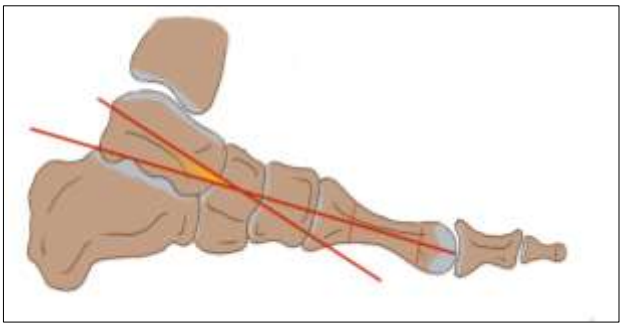

Figure 5: Meary angle.

Statistical analysis

The type of TMT fixation done was noted. The feet were then separated into 6 simplified groups depending on the fixation performed; dorso-medial plate with 1 screw, dorso-medial plate with 2 crossed screws, dorsal plate with 2 crossed screws, dorsal plate with 1 screw, medial plate with 2 crossed screws and medial plate with 1 screw (Table 1).

Table 1: Fixation group codes for analysis.

Type of fixation	Group code
Dorso-medial plate with 1 screw	G1
Dorso-medial plate with 2 crossed screws	G2
Dorsal plate with 1 screw	G3
Dorsal plate with 2 crossed screws	G4
Medial plate with 2 crossed screws	G5
Medial plate with 1 screw	G6

The descriptive statistics used were means and inferential statistics used were paired student t-test, one-way analysis of variance (ANOVA) and intraclass correlation coefficient (ICC). Measurements from single screw and crossed screw were compared using paired student t-test and radiographic measurements from plate groups were compared using one-way ANOVA. Interobserver reliability of radiographical measurements of the angles (HVA, IMA, DMA, Meary angle, MDA) was calculated using ICC. The student t-test was performed using Microsoft Excel. ANOVA was done using STATA and ICC was calculated using statistical package for the social sciences (SPSS). P values less than 0.05 were considered statistically significant. Values for ICC were based on the study by Cicchetti and Sparrow, with 0.75-1 being excellent and <0.4 being poor.

RESULTS

A total of 35 patients who underwent LP during this time were identified. A patient's record is used twice if they

have had both feet done. Records were missing for a total of 10 feet. Out of the 25 feet remaining, 12 feet were eligible for the study according to the inclusion and exclusion criteria. 75% (7 patients) feet were female and 25% (3 patients) feet were male in the study.

The pre– and postoperative ICC of HVA, IMA, DMA and Meary angle demonstrated high to excellent interobserver reliability with their lower limit of 95% CI all being >0.4. The pre- and postoperative for DMA demonstrated fair interobserver reliability but the lower limit of 95% CI were –0.53 and 0.2 for pre-op and post op respectively which were in the poor interobserver reliability of <0.4 (Table 2).

Types of fixations

The feet were identified into different groups of fixations. There were 5 patients identified in the dorso-medial plate with 1 screw group (G1), 2 patients in the dorso-medial plate with 2 screws group (G2), 2 patients in the dorsal plate with 1 screw (G3), 1 patient in the dorsal plate with 2 screws (G4), 2 patients in the medial plate with 2 screws (G5) and 0 patients were identified in the medial plate with 1 screw group (G6). The means of the difference in pre-op minus post-op angle (Δ-angles) for angles HVA, IMA, DMA, Meary angle and MDA were calculated for each group. G1 showed the largest change in mean angles for HVA and DMA. G4 showed the largest change in mean angles for IMA. G2 showed the largest change in mean angles for meary angle and G5 showed the largest change in mean angles for the MDA. There were no plantar plates identified.

Plate + single screw versus plate + crossed screw

The mean Δ-angles for crossed screw were 15.5 (HVA), 3.67 (IMA), 10.9 (DMA) 1.31 (Meary angle) and 0.31 (MDA). The mean Δ-angles for single screw were 25.59 (HVA), 7.41 (IMA), 24.31 (DMA), 0.02 (Meary angle) and –1,24 (MDA). The mean change in angles for HVA, IMA and DMA were higher with the single screw fixation while the mean change in angles for Meary angle and MDA were higher with the crossed screws group shown by Figure 7.

The paired student t-test was performed to check for statistical significance of the results from the mean values. The p values from comparing crossed screw vs single screw for the angles were obtained; HVA was 0.086, IMA was 0.3, DMA was 0.029, Meary angle was 0.71 and MDA was 0.65 (Table 3). The distal metatarsal articulate angle (DMAA) had p value of 0.029 (<0.05) which was statistically significant between the two groups. The other angles did not show statistical significance.

Dorso-medial plate versus medial plate versus dorsal plate

The mean Δ-angles for dorso-medial plate fixations were 25.1 (HVA), 7.19 (IMA), 21.78 (DMA), 1.39 (MA), and –0.71 (MDA). The mean Δ-angles for dorsal plate fixations were 16.92 (HVA), 6.45 (IMA), 15.48 (DMA), -1.23 (MA) and 0.02 (MDA). The mean Δ-angles for medial plate fixations were 14.93 (HVA), 0.25 (IMA), 12.86 (DMA), 0.33 (MA) and –0.07 (MDA). The mean change in all angles (HVA, IMA, DMA, Meary angle, MDA) were higher with the dorso-medial plate fixations followed by dorsal plate fixations for all angles except MA.

The one-way ANOVA test was performed to check for statistical significance of the mean values. The p values from comparing the plates were obtained; HVA was 0.33, IMA was 0.36, DMA was 0.55, Meary angle was 0.81 and MDA was 0.7. No p value was <0.05 and so there was no statistical significance.

Table 2: Intraclass correlation coefficient results.

Parameters	Intraclass correlation coefficient (95% CI)				
	HVA	IMA	DMA	MA	MDA
Pre-operative	0.88 (0.6-0.96)	0.98 (0.86-0.99)	0.83 (0.4-0.95)	0.9 (0.64-0.97)	0.6 (-0.53-0.89)
Post-operative	0.98 (0.93-0.99)	0.98 (0.92-0.99)	0.97 (0.91-0.99)	0.96 (0.86-0.99)	0.7 (0.2-0.9)

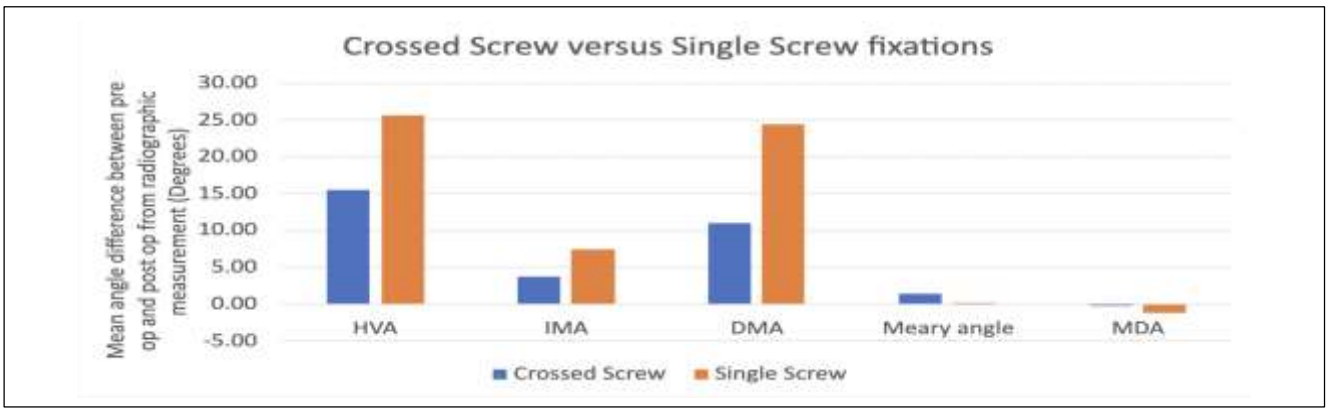

Figure 6: Bar chart of crossed screw versus single screw angles.

Table 3: P values for all angles comparing crossed screw versus single screw fixations.

Variable	HVA	IMA	DMA	MA	MDA
P value	0.086	0.3	0.029	0.71	0.65

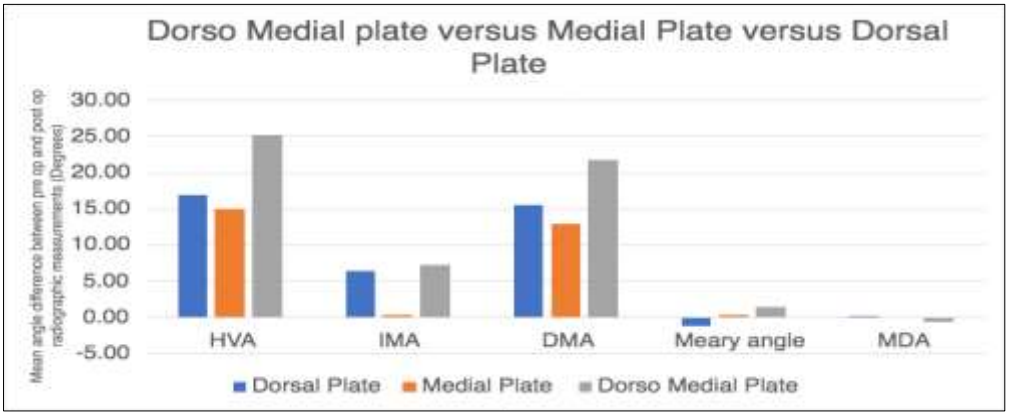

Figure 7: Bar chart for dorso-medial plate versus medial plate versus dorsal plate.

Table 4: P values for all angles comparing dorso-medial plate versus medial plate versus dorsal plate.

Variable	HVA	IMA	DMA	MA	MDA
P value	0.33	0.36	0.55	0.81	0.69

DISCUSSION

Hallux valgus is considered a major public health issue and is predicted to increase in prevalence due to ageing population.[10] It has also been associated with other pathologies affecting the second ray, which can make management difficult.[11] Furthermore, worsening hallux valgus is associated with a reduced quality of life, as seen in a study with the elderly and women who are both high risk groups at developing hallux valgus.[12,13]

It is a treatable deformity with arthrodesis of the first tarsometatarsal joint being an established method of treatment. Many variations of the procedure exist, and they make use of different techniques and fixation methods. It is more common to see surgeons performing the modified version of the Lapidus procedure over the original method. The key difference is omitting arthrodesis of the metatarsal bases.[10] In terms of fixation methods, Menke at al described combinations of K-wires, plates and screws, staples and internal fixations are shown to effectively stabilize the joint.[14] With the constant development of new methods of fixations, with the aim of decreasing complications and enhancing technique, several papers in the literature seek to compare the efficacy of these methods and if there is, at all, a superior LP fixation.

This study attempted to demonstrate statistically significant differences in radiographical measurements between the methods of fixation in our cohort of patients. In the comparison of crossed screws vs single screw, the DMA showed statistically significant changes in pre-operative and post-operative X-ray angle measurement.

A study found that DMA values were significantly higher in patients with hallux valgus compared with the non-diseased control group but stated that 2D radiographic methods could lead to overestimation of this triplanar deformity.[15] The validity and reliability of the first distal metatarsal articular angle has been tested in several studies. Cruz et al concluded that producing a 3D analysis of the DMA increased the interobserver reliability compared to conventional radiographs.[16] A laboratory study experimented with 6 cadaveric first metatarsals through a sequence of orientation changes. They compared conventional radiographic measurements with measurements where the first distal metatarsal articular surface was circumscribed with metallic paint.[17] This opens up novel and accurate methods to measure the DMA.

The results from this study produced a spread of data that single screws appear to be superior to crossed screws in terms of change in angle pre op and post op, although only DMA was statistically significant. A larger sample size could produce statistically significant results. A study with 40 patients found that fixation with a locking plate + plantar screw lag resulted in successful healing that was not compromised by weight-bearing initiated at 4 weeks, as opposed to crossed screw fixation where weight bearing is avoided till after 6-weeks postoperative phase. Although, there was no statistically significant change in angle correction between the two groups.[18] This is further supported by Menke et al, with 21 feet, where fixations with 1 interfragmentary screw and a locking H-plate provided sufficient stability for earlier weight bearing than compared to traditional timescales.[14] There is evidence

that systems with single screws have certain benefits against crossed screws. However, there is a scarcity in studies that compare plate-single screw versus plate-crossed screws.

A biomechanical study was done to evaluate the strength and stiffness of subtalar joint arthrodesis screw constructs. A single posterior screw, two posterior minimally divergent screws and two highly divergent screws constructs were compared. Surrogate bones with these constructs had inversion and eversion forces applied. Two highly divergent screws construct had the largest stiffness and torque and this shows that two screw constructs generally have more stiffness than single screw constructs.[19] However, stiffer constructs are associated with poorer bone healing as mentioned by Terjesen et al who published a paper on 'the influence of different degrees of stiffness of fixation plates on experimental bone healing'. Tibial osteotomies were performed on rabbits using plates with 4 varying degrees of stiffness. The bones healing was then studied and compared. This study concluded that steel plates with less stiffness were more appropriate for bone healing.[20] The results pertaining to our study which shows single screw systems resulting in better post-operative angle changes compared to crossed screws are consistent with this concept.

Our results showed average change in angles for the plates group were higher for the dorsomedial plate position followed by dorsal the medial, although it was not statistically significant. A study discussed the main advantages of a dorso-medial anatomical plate placement. It stated that there was significant improvement of radiographical measurements postoperatively of patients' feet ($p<0.05$) alongside other advantages such as ease of placement, high stability of the TMT joint and no irritation/impingement on the anterior tibialis tendon from hardware.[21] A study by Drummond et al mechanically investigated different anatomically positioned plates (plantar, medial, dorsal) having identical interfragmentary screws. The variable was the plate position. The outcomes measured were stiffness, yield force, displacement at yield, ultimate force, and displacement at ultimate force.[22] The plantar plates proved to be the most superior, followed by the medial plate. The dorsal plate showed no superior results. Our results vary from this conclusion, and it could be due to the medial plate having the lowest numbers from our data collection.

A systematic review was conducted (published 13 July 2021) by Lopez-Lopez et al to analyse the effectiveness of several Lapidus plate systems in foot surgery and within this fourteen studies were selected and had an overall of 738 cases. It concluded that there is a need to increase the knowledge surrounding the different types of Lapidus fixations.[23]

The limitation of our study is that it has a retrospective design, and the results depend on the accuracy of record keeping. Convenience sampling method was used sample size was small compared to other studies and it was not possible to analyse data from plantar plate fixations. Another limitation is the oversimplification of fixation types for convenient grouping. The follow-up periods varied between patients as the final post-operative X-ray was used. In shorter follow-up periods, it is not clear if there was continued loss in deformity correction and whether the angles remained stable.

CONCLUSION

This study attempted to measure the differences of change in angle among the fixation methods in the Lapidus procedure and to identify the fixation method that produces the best radiographical measurements. The results showed statistically significant ($p<0.05$) change in radiographic measurements for distal metatarsal articulate angle (DMA) in the plate-single screw and plate-crossed screw group. Within the plate groups, dorso-medial plate showed the largest change in angle although it was not statistically significant.

Recommendations

Further comparative and prospective studies with larger sample size are required to evaluate the differences in fixation groups before generalising the results. It is recommended that studies of similar value to Drummond et al also be run with the plate position standardized and the variable as the screws allowing us to appreciate the direct effect of the type/number of screws on the outcomes.

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