Effects of repeated usage on microvascular clamp occlusive force

Ronald M. Friedman, M.D.
G. Stewart Campbell, M.D.
Quian Dai, Ph. D.

Loma Linda, California

From the Department of Orthopaedic Surgery and Biomechanics Laboratory,
Loma Linda University Medical Center,
Loma Linda, California.

ABSTRACT

The occlusive forces of 55 metal clamps (ST-B-2V clamp, ASSI Corp.) were studied with a pressure transducer. The new clamps (n=16) had a mean force of 39.5 g (SD 3.2g), whereas the used clamps (n=39) had a mean force of 50.1 g (SD 9.5). This 27% increased force in used clamps was statistically significant (p<0.0005), independent samples t-test) and is likely due to work-hardening of the metal alloy with repeated usage. The increased pressure may lead to microvascular injury and thrombosis. Our data supports the usage of disposable microclamps to optimize safety in small vessel (1mm) anastomosis.

INTRODUCTION

The application of microvascular clamps to occlude vessels during anastomosis may be associated with vessel damage and thrombosis. 1-5 We have had the recent misfortune of verifying this phenomenon clinically on two occasions, both of which resulted in flap loss.

A variety of innovative clamp designs have been suggested in an attempt to minimize associated vascular injury. 6-12 Many of these are disposable clamps intended for single usage. Most surgeons, however, continue to use conventional metallic microvascular clamps, which may be used repeatedly. Based on our adverse experiences with used metal clamps, we hypothesized that repeated usage may result in an increase, rather than a decrease, in occlusive force.

MATERIALS AND METHODS

A pressure transducer was designed and built using commercially available materials and a strain gage (Precision Strain Gages, Measurements Group Inc., Raleigh, NC) (Fig. 2). The transducer was calibrated using new polycarbonate clamps (Biover Clamp) with known occlusive forces of 20, 30, 40, and 60 grams. A linear relationship between occlusive force and strain gage readings was noted. The occlusive forces of 55 metal alloy microvascular clamps, all of the same model and manufacturer, were then measured (ST-B-2V clamp, ASSI Corporation, Westbury, NY). Each clamp was tested three times using two independent strain gage responses. Average readings were recorded for each clamp.

The metallic clamps tested included 16 new clamps and 39 clamps that had been subject to repeated usage, approximately 50 to 75 times in the operating room or microvascular laboratory. The clamps used in the operating room (n=12) had been autoclaved between uses, whereas the clamps used in the lab (n=27) had not been autoclaved.

RESULTS

Mean occlusive force of the new metallic clamps (n=16) was 39.5 g (SD 3.2). In contrast, the average occlusive force of the repeatedly used clamps (n=39) was 50.1g (SD 9.2). This 27% increase in mean occlusive force with repeated usage is significant to statistical testing (p<0.0005, independent samples t-test). It represents an increased force in the used clamps of over 3 standard deviations from the mean force observed in the new clamps. The measured force did not vary significantly between the autoclaved (n=12, mean force 49.6 g) and non-autoclaved (n=27, mean force 50.3) clamps.

DISCUSSION

The adverse effects of applying microclamps possessing too much occlusive force are well described by Thurston et al. 4 Within 20 minutes of clamp application, they observed fusiform aneurysmal dilation, proximal and distal vasospasm, and massive endothelial sloughing with en masse platelet and leukocyte adherence at the site of clamp application. Based on these observations, they recommended the usage of clamps that produce a pressure less than 30 g/mm2.

The ST-B-2V metal clamps that we studied have a measured jaw width of 1.7 mm and are designed for use on vessels averaging 1mm diameter (range 0.6 to 1.5 mm). 13 The pressure and generated at the site of vessel occlusion equals the clamp force in grams divided by the surface area of the application in square millimeters. Therefore, for a 1mm vessel, the new clamps averaged and occlusive pressure of 23.2 g/mm2 while the used clamps averaged 29.5 g/mm2. None of the new clamps exceeded the safe pressure defined by Thurston et al.4 However, 16 of the 39 used clamps exceeded a pressure of 30 g/mm2, and pressures as high as 43.5 g/mm2 were observed.

Yoshii et al. 6 have noted that "with frequent application, the clipping power of (metallic clamps) may be changed, because of the deformation of the clip shape or elongation of the coil spring, i.e. they are not always in as good condition as new ones." To our knowledge, however, the present study represents the first effort to test the reliability of metallic microclamps subjected to repeated usage. Given the virtually equal forces in the autoclaved and non-autoclaved clamps, the autoclave process does not appear to be responsible for the increased occlusive force seen in used clamps.

We believe that the study results are best explained by the phenomenon of metal work hardening, which is a fundamental engineering concept. 14 Each time the clamp is opened and closed a force (P) occurs at the spring site (A). This is transmitted as a bending moment arm of force (PL1) to points B and C. With repeated clamp usage, the tensile stress may exceed the material's limit, resulting in plastic deformation of the metal. This causes the metal to become more resistant to further deformation, resulting in a stiffer, stronger clamp that generated an increased force.

We have demonstrated that repeated usage of ST-B-2V microclamps results in a statistically significant increase in occlusive force, which may lead to microvascular damage and thrombosis. Our data supports the usage of disposable clamps to optimize safety in small vessel (1mm) anastomosis.

REFERENCES

1. Gertz SD. Renneis ML, Forbes MS. Endothelial cell damage by temporary arterial occlusion with surgical clip site by scanning and transmission electron microscopy. J. Neurosurg. 45:514, 1976.
2. Stamatopoulos C, Biemer E, Duspiva W. Microvascular damage caused by the application of surgical microclips: The effects of pressure and time. Internat. J. Microsurg. 2:81, 1980.
3. Yanase U, Uebe Y, Sudo Y. An experimental study on traumatic changes in microvessels produced by pressure clamping. Aust. NA J. Surg. 50:423, 1980
4. Thurston JB, Buncke JH, Chater NL, Weinstein PR. A scanning electron microscopy study of micro-arterial damage and repair. Plastic. Reconstr. Surg. 57:197, 1976.
5. Chow SP, Zhu JK, So YC. Effect of bipolar coagulation and occlusion clamping on the patency rate in microvascular anastomosis. J. Reconstr. Microsurg. 1:41, 1984.
6. Yoshii, T Tamai S, Mizumoto S, Vajima H, Huang WC. A new disposable microvascular double clip. J. Reconstr. Microsurg. 3:133, 1987.
7. Ikuta Y: Microvascular double clamp type A-11. Reconstr. Microsurg. 1:41, 1984.
8. Stark RH, Sanger JR, Matloub HS. A new microvascular clamp for the production of experimental ischemia. Microsurgery 5:202, 1984.
9. DeCarolis V, Kuijis R. A simple adjustable microvascular clamp with a controllable gentle occlusion mechanism. Plast. Reconstr. Surg. 70:100, 1982.
10. Govila . A simplified microvascular clamp. Br. J. Plast. Surg. 42:347, 1989
11. Naryanan K, Liang MD,Schichman D.A new variable-pressure microvascular clamp.Microsurgery 9:52, 88.
12. Smahei J, Laszczower M. New disposable microvascular clamp. Microsurgery 6:129, 1985
13. Instrument catalog, Accurate Surgical & Scientific Instruments Corporation, G-2 edition, pp M34-37.
14. Goldman JE. The Science of Engineering Material, New York, John Wiley and Sons, Inc. 1957.

TABLE I

Measured Occlusive Forces of New and Repeatedly Used ST-B-2V Metallic Microclamps

	New	Autoclaved	Non Autoclaved
Number	16	12	27
Mean occlusive force (g)	39.5	49.6	50.3
Standard deviation (g)	3.2	9.9	9.1
Range (g)	34.0-44.4	39.2-74.0	38.9-67.7