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ORIGINAL ARTICLE

Histologic and Ultrastructural Evaluation of Sutures Used for Surgical Fixation of the SMAS

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Abstract In extensive SMAS face-lift surgery, retaining ligaments are released, and the SMAS is resutured to the deep fascia to maintain the advanced position. The suture used to reattach the SMAS should replicate the quality of support provided by the original ligaments. Nonabsorbable sutures (monofilament and braided) retrieved intraoperatively from 22 patients undergoing secondary face-lift procedures were examined by light microscopy and transmission electronmicroscopy. A distinctive enclosure of dense collagen and elastin formed around both types of suture. Based on the presence of inflammatory cells, fibroblasts, collagen, and elastin, the tissue reaction to monofilament suture was less than with the braided suture. The collagen and elastin were thicker around the braided suture, and, additionally the collagen matrix infiltrated between the individual filaments. Ultrastructural analysis of the braided suture showed significant collagen binding around each individual filament. The greater quantity of connective tissue around the thread which continued into the interstices of the braided suture has the characteristics of a ligament. This suggests a stronger and more lasting tissue fixation.

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In principle, when the SMAS (superficial musculo-aponeurotic system) flap techniques (composite and extended separate SMAS flap) are used in facial rejuvenation surgery, it involves the surgical displacement of the SMAS away from the area of facial laxity [6]. The initial surgical step requires the release of the SMAS from the retaining ligaments that anchor the relevant part of the SMAS to the underlying deep fascia. Secure fixation of the SMAS in the advanced position is fundamental to achieving the desired result and to avoid possible "relapse." For this reason, the SMAS is fixed to the immobile periosteum of the zygoma and adjacent deep fascia (the deep temporal or masseteric fascia) [5]. Use of the most appropriate suture material is paramount given that the support provided by the retaining ligaments has been eliminated by the dissection and is to be replicated by the surgical fixation.

In general, the main factors considered in selection of a suture include the tensile strength, durability, tissue reactivity, and the intrinsic material characteristics which determine ease of use and knot palpability. The fact that a range of suture materials is currently used in SMAS surgery may reflect on surgeons having different priorities and possibly on the absence of complete information regarding the long-term tissue response to the various types available. Monofilament sutures have the proven benefit of minimal tissue reaction and a lower rate of infection [1], while braided polyester has the advantage of maintaining tensile strength over time [3, 11]. Given that the SMAS is maintained in place by retaining ligaments [2], it would seem

logical to use whichever suture material provides the most ligament-like properties of strong and lasting support.

This histologic and ultrastructural study was undertaken to evaluate the long-term tissue response to monofilament and braided suture used in SMAS surgery.

Materials and Methods

In the course of 22 secondary facelift and temporal lift procedures, specimens of suture material from previous surgery performed by the senior author were retrieved within a segment of the surrounding tissue. The patients were 38 to 62 years of age, and the sutures had been *in situ* from 6 months to 10 years. In 18 patients, the sutures obtained were braided, and from 4 patients the suture was monofilament.

The samples allocated for light microscopy were fixed in 10% buffered formaldehyde for a minimum of 24 h. To preserve the architectural relationship during sectioning, the tissues were treated for 48 h with a 10% phenol solution to allow the synthetic suture material to soften. Paraffin blocks were cut at a thickness of 7 μm and stained with hematoxylin and eosin or Gomori trichrome.

The braided samples prepared for electronmicroscopy analysis were fixed in a mixture of 3% glutaraldehyde, 2% formaldehyde, and 0.1% picric acid buffered in 0.1 M cacodylate, pH 7.4, for 4 h at 4°C. Following postfixation in cacodylate-buffered 2% osmium tetroxide, the tissues were rinsed in buffer and processed into polymerized blocks of Epon-Araldite using standard methods. Sections for initial light microscopy to determine tissue quality and architecture suitable for ultrastructure were cut at 1 μm and stained with toluidene blue. For electonmicroscopy, thin sections were cut with a diamond knife, mounted on copper grids, stained with lead citrate and uranyl acetate, and examined using a Jeol 100S electron microscope.

It was difficult to obtain exact transverse section of the monofilament suture due to the residual rigidity of the suture material on the microtome knives and the orientation of the suture–tissue mass within the embedding media. The transverse and oblique sections examined together gave sufficient insight into the characteristics of the surrounding collagen network. In addition, there was an insufficient quantity of monofilament samples available for electronmicroscopy.

Results

Both the monofilament and the braided sutures were separated from the surrounding cuff of normal tissue (the outer tunica) by a new arrangement of cellular and collagen tissue (the inner tunica). This was tubular in shape being concentric with the suture. This arrangement of the interface with the normal tissue appeared similar in character for both suture types, but varied in degree. The contrasting surface structure of the two suture types is easily seen through scanning electron micrographs (Fig. 1).

In both types existed a compacted inner tunica of collagen adhered to the suture and a looser, more chaotic outer collagenous tunica blending into the surrounding tissue (Figs. 2–7). The inner tunica around the monofilament suture was completely smooth at the suture interface, where it was compacted with a uniform concentric collagen arrangement (Figs. 2 and 3). In addition, numerous elastin fibers extended through to the outer tunica where they became thick and highly convoluted.

The outer tunica of collagen around the braided thread was considerably thicker than around the monofilament thread (Figs. 4–7), and gave the appearance of integration with the surrounding tissue (Figs. 6–7). The braided thread also induced a much thicker inner collagenous tunica and lacked a smooth interface with the surface of the braided thread (Fig. 6). This is due to collagen not remaining outside the perimeter of the suture as observed with the monofilament thread. Rather, fibroblasts invaded the interstices, not only between the woven segments of filaments (Fig. 5), but also between the individual filaments. Ultrastructural analysis showed a smooth, even interface of the fibroblast and collagen response around each individual filament rather than to the braided suture thread as a whole (Fig. 9).

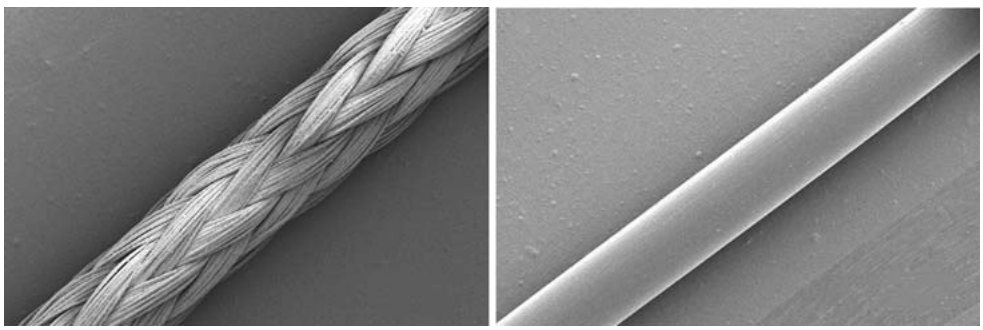

Fig. 1 Scanning electron micrographs of the surface of an Ethibond™ braided polyester suture (**left**) and surface of the solid monofilament suture, Prolene™ (**right**). (Images courtesy of Johnson & Johnson)=

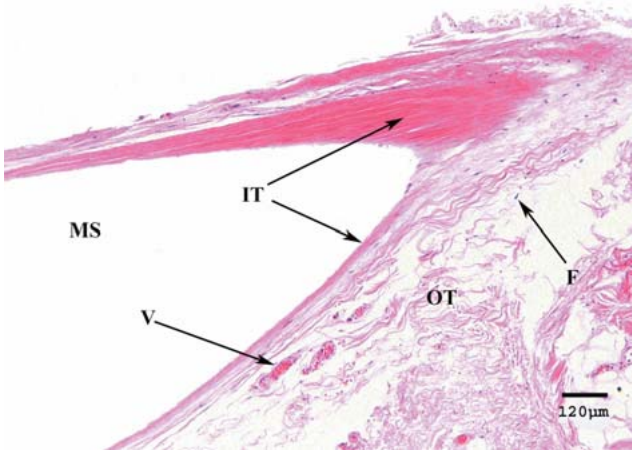

Fig. 2 Monofilament suture from temporal region, 6 years in-situ, H&E stain, oblique section. This staining reveals collagen as light pink with fibroblasts and other connective tissue cells as purple. The inner tunica (**IT**) of collagen is thin and dense, seen encapsulating the suture (**MS**). Fibroblasts (**F**) and vessels (**V**) are distributed throughout the outer tunica (**OT**) of loose connective tissue=

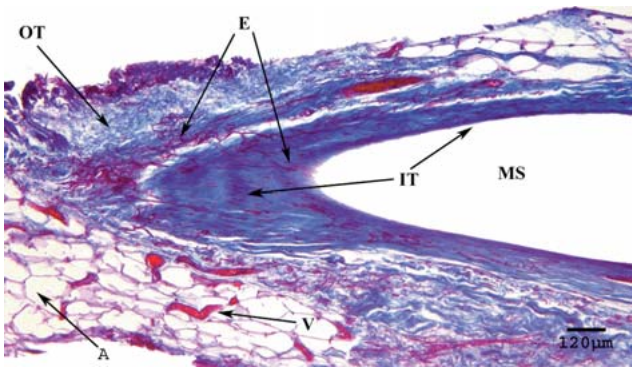

Fig. 3 Monofilament suture from masseteric region, Gomori Trichrome stain, oblique section. Collagen is interspersed with numerous elastin fibers (**E**). The vessels (**V**) and adipocytes (**A**) of the surrounding tissue outside the loosely arranged outer tunica (**OT**) which is distinct from the thin, compact inner collagen tunica, (**IT**) is shown adhered to the suture (**MS**). The elastin fibers (purple) continue from the inner through to the outer tunica (**OT**) and became thicker and coiled. The elastin fibers within the inner tunica are smaller in both length and diameter when compared to braided suture=

The presence of fibroblasts and neocollagenesis within the braided suture was remarkable for both the arrangement and the extent of the tissue response. The braided suture was uniformly involved with the formation of concentric whorls of collagen containing fibroblasts, confined predominantly to within the inner half. This occurred around each filament of the thread, not only around the fragments of braid near the periphery as may have been expected (Figs. 5–8). The total cross-sectional area of new collagen in some specimens was similar to that of the filaments, and

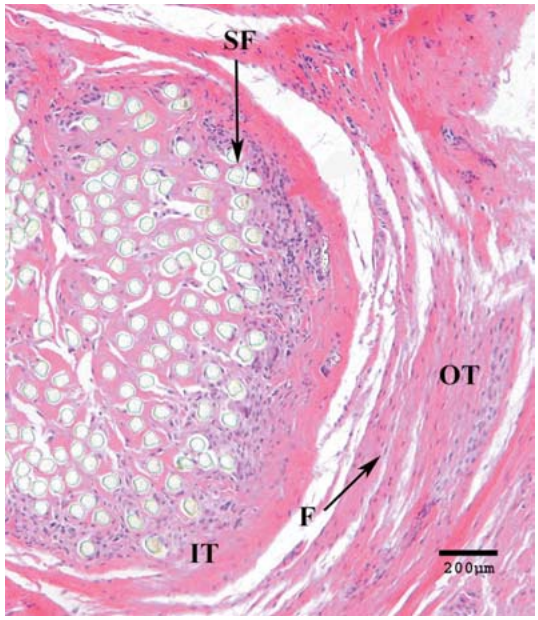

Fig. 4 Braided suture retrieved from temporal region, 2 years in-situ, H&E stain. Inner tunica of collagen (**IT**) containing suture filaments (**SF**) is distinctly separate from the outer tunica (**OT**) of collagen shown. Fibroblasts (**F**) are seen in large numbers interspersed throughout the sample=

in others considerably greater than that of the suture material itself (Fig. 8).

Discussion

In most surgical procedures, there is no functional requirement for suture support once the wound has gained sufficient tensile strength. However, this may not be applicable in deep fixation of the SMAS as the desired result may depend on the continued integrity of the suture. The reason for this relates to the nature of the SMAS attachment. Anatomically, the SMAS is fixed to the underlying deep fascia in a discontinuous manner by a series of "retaining ligaments." Between the regions of ligaments are larger areas of nonadherence (glide planes). The areas of SMAS nonadherence allow for mobility of the face [6]. Examples include the temporal [8], prezygomatic [7], and buccal spaces. When accounting for these areas of mobility, it is not anticipated that a broad area of fibrous adhesion would develop after deep suture fixation of the SMAS has occurred.

The inherent strength of the retaining ligaments may be an indication of the fixation strength functionally required in each area of the SMAS. If such is the case, the original ligaments should be surgically replicated, not only in the correct location, but also with appropriate strength. In general, postoperative loss of suture fixation is most often due to the suture material "cutting through" the enclosed

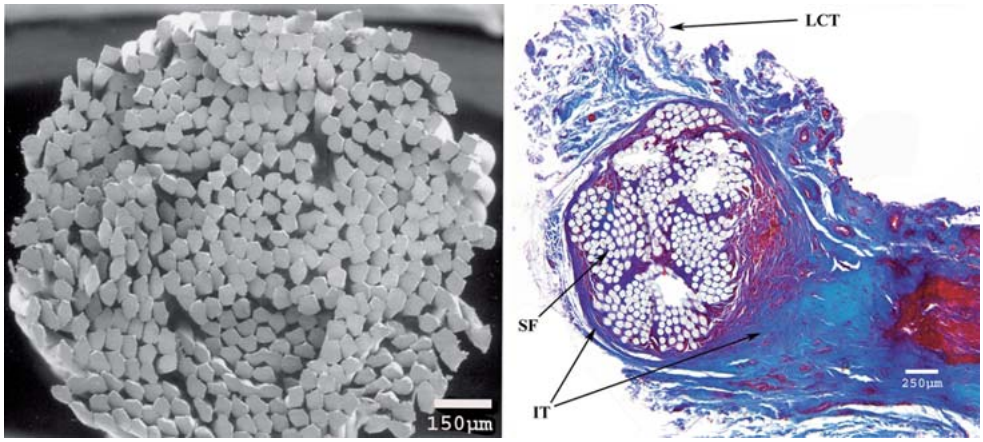

Fig. 5 Scanning electron micrograph of a braided thread, cut transversely (**left**) and braided suture from temporal region, 4 years in-situ, Gomori Trichrome stain (**right**). Ultra fine elastin fibers, (seen as deep purple strands) are interspersed within the collagen mass (light blue). Infiltration of collagen between the filaments (**SF**) is observed within the inner tunica (**IT**). Loose connective tissue (**LCT**) is seen to separate away. Variation in collagen color (red and blue) is attributed to the reaction of the stains with the protein composition of the collagen and is not of histological significance=

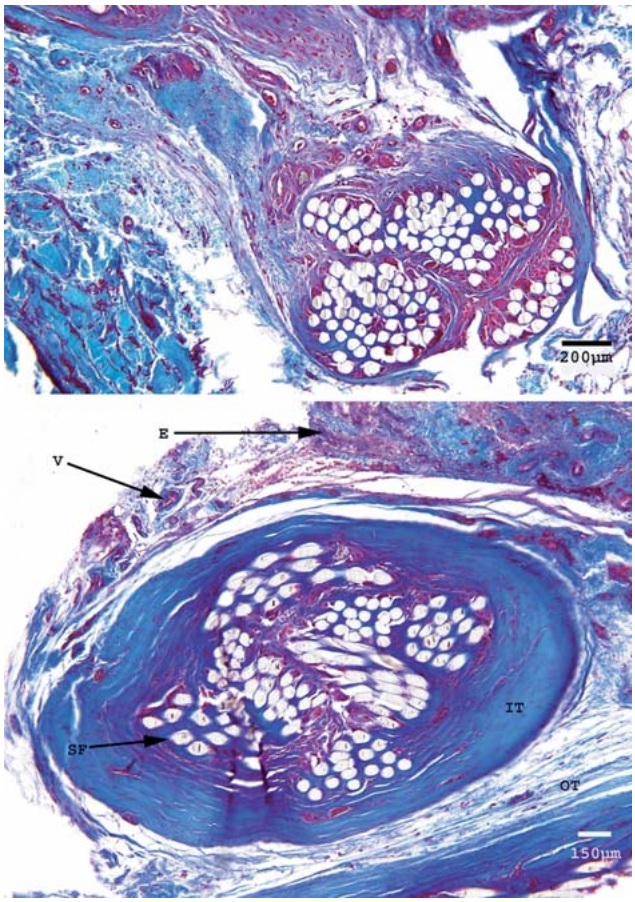

Fig. 6–7 Braided sutures from zygoma region, 4 years in-situ (**above**) and 10 years in situ (**below**) stained with Gomori Trichrome. Both samples have substantial infiltration of collagen throughout the filaments (**SF**). The suture 10 years in-situ has a considerably thicker inner tunica (**IT**) and it can also be seen that vessels (**V**) and elastin (**E**) are confined predominantly to the outer tunica (**OT**)=

bite of soft tissue rather than knot slippage or a failure of the suture material itself [10]. It is the fibrous component within the soft tissues that supports or holds the loop of suture within the flap. The additional infiltration of the connective tissue throughout the braided filaments was seen to be significant at histologic examination. The concept of suture material stimulating a superior fibrous fixation within the immediately surrounding tissue is appealing. This is due to the likelihood that the fibrous tissue developing in response to the braided suture will integrate with the tissue being supported and reduce the possibility of the suture loop "cutting through" from its insertion over the long term.

The presence of inflammation shown by the arrangement of lymphocytes and neutrophils concentrated immediately around the synthetic fibers and dispersed throughout the inner collagen shell has been noted previously [11, 12, 14]. This shows further the extensive biologic response that suture material initiates once placed within soft tissue. The fibroblasts have a remarkable ability to penetrate through the braided suture, and as the individual filaments are separated, the overall diameter of the thread increases. Similar, histologic studies have shown that collagen develops between the filaments as early as 30 days [11, 14]. The presence of fibroblasts and collagen around each fiber demonstrates ongoing production of collagen and connective tissue accumulation. The degree of infiltration between samples of 6 months and 10 years showed negligible difference, suggesting that most collagen deposition occurs by 6 months *in situ*.

The volume of collagen separates the filaments to such a degree that in some specimens, the greater part of the

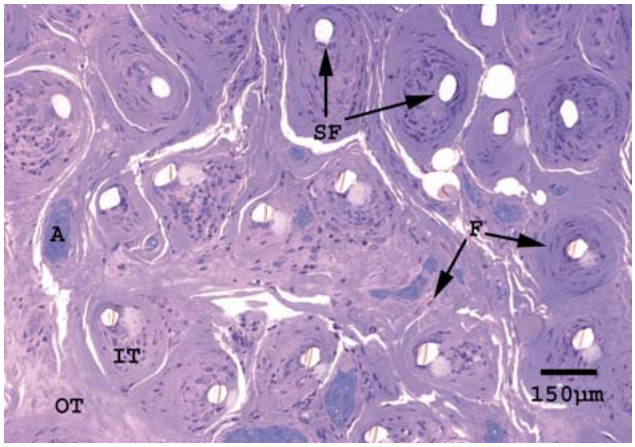

Fig. 8 Epon araldite embedded, braided suture from zygoma region, 5 years in-situ, toluidine blue stain. Preservation of architecture is improved compared to paraffin sections due to the increased density of the embedding medium. Note the uniform concentric arrangement of collagen within the inner tunica (**IT**) and fibroblasts (**F**) around each filament (**SF**) of the braided suture. The outer tunica (**OT**) which can be seen to develop throughout the filaments also contains adipose tissue (**A**). The fibroblast and collagen response is significant being up to five times the diameter of the central filament=

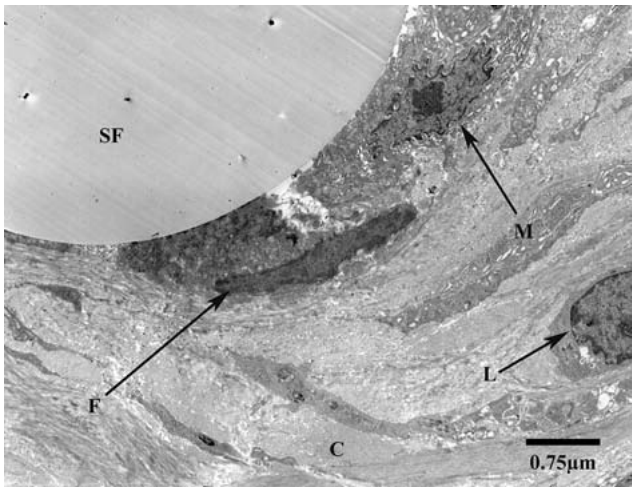

Fig. 9 Transmission electron microscopic image of a braided suture filament from the zygoma region. Fibroblast nucleus (F) within the collagen matrix (C), in close proximity to the braided filament (SF) A. macrophage (M) and part of a connective tissue cell or monocyte (CM) are indicated=

braided suture's surface area is occupied by the newly generated fibrous tissue. This "neoligamentous" arrangement, also previously shown [11], is proven to maintain volume over the long term. This may explain the observation that synthetic braided sutures have no significant reduction in strength after 2 years *in situ* [3].

The arrangement of elastin within the fibrous tissue surrounding the suture mimics that occurring elsewhere in the body with respect to ligaments having the requirement for high tensile strength (inner tunica binding to the thread) and low tensile strength (surrounding loose connective tissue). This arrangement is reflective of the strong association between elastin arrangement and ligament function. The arrangement of the elastin within the inner tunica of collagen (dispersed between the fine and parallel collagen fibrils) is similar to that within the spinal longitudinal ligaments and the ligamentum flavum, both of which require high levels of tensile strength [4, 13]. The outer tunica of collagen, which contains elastin, was less organized and highly coiled, similar to that in large vessels or spinal dura [9, 13]. The braided suture has effectively acted as a nidus for the collagen and elastin to develop similar to a neoligament.

Fixation of tissue specimens for electronmicroscopy preserves the architecture to show precise tissue relationships as well as high resolution of cellular detail. This investigation highlighted the intimate proximity that the connective tissue developed around the synthetic filaments. The solid monofilament suture precludes connective tissue infiltration. The minimal inflammatory cellular response associated with the smooth surface and decreased surface area comes at a compromise of an enormously reduced area for adherence of the collagen compared to the multifilament braided thread.

The significance of these findings may apply to other procedures in which lasting fixation is required. In Canthopexy, for example, the weakest link in maintaining the elevated lateral canthal position long term is the risk of the suture cutting through the mobile lateral canthal ligament. In addition, threadlift surgery relies on barbs on the surface of monofilament sutures to "hook" into the subdermal soft tissues that require lifting or tightening. The failure of barbed threads to maintain the position over time is presumably due to the cogs cutting through the supported soft tissues. A braided barbed thread has the potential to offer more lasting results given the enhanced fibrous attachment resulting from the braided suture interfacing with the tissues.

Conclusion

The long-term tissue response to nonabsorbable monofilament and braided suture as used in facial rejuvenation surgery was compared. Both sutures were the focus of a neoligament type of response with the formation of collagen and elastin, not dissimilar to ligaments elsewhere in the body. The monofilament suture was surrounded by a thin inner layer of compact organized collagen, around which was an outer, less organized layer. The fibrous tissue response to the braided suture was significantly greater.

The outer layer of collagen in the tissues was continuous, with a thicker, dense inner layer that continued inside the braid with a major ingrowth of fibroblasts and collagen between and around each individual suture filament. The cross-section area of collagen within the suture was equal to or greater than that of the braided suture material.

The integration of the fibrous tissue around each individual filament of the braided thread as well as the greater collagen reaction at the tissue interface implies superior tissue fixation. For this reason, in addition to the benefits of a more supple material, braided nonabsorbable suture is preferred for deep fixation of the SMAS.

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