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Experimental analysis of tensile properties of some suturing materials

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The aim of the investigation is to quantitatively evaluate the failure load of several suture materials currently used in dentistry surgery. No chromic catgut, silk, Prolene, Ethilon, Ethibond, Vicryl and Vicryl Rapid, obtained from Ethicon s.p.a., in the sizes 3–0, 4–0, and 5–0 have been tested. The analysis has been carried out measuring the diameter of each suture with an optical microscope to determine the accuracy of manufacturers' data. Tensile testing has been performed to evaluate the failure load of each material. Finally, sutures of the same effective diameter class have been compared relative to failure load. Results show that monofilament sutures present a failure load remarkably superior to that of multifilament sutures. Using SEM analysis monofilament sutures present less surface irregularities than multifilament sutures. Only monofilaments Ethilon 4–0 and 5–0, Prolene 4–0, and multifilament no chromic catgut 4–0 and 5–0 meet the requirements of the Italian Pharmacopeia. In contrast, Prolene 5–0 and the other multifilaments, silk, Ethibond, Vicryl and Vicryl rapid, have a larger diameter than that declared on the label by the producer.

1. Introduction

Since prehistoric times sutures have been used to reapproximate soft tissues [1]. In recent times refinements in manufacturing processes have resulted in improvements in physical and biological properties of suture materials. The qualities of the ideal suture material have been compiled by Postlethwait [2] and later reviewed by several authors [3–5].

Two of the most important properties are failure load, to provide adequate tension for wound closure, and non-reactivity in order to provoke the least inflammatory response [6, 7]. This last property depends on the material, on the shape (monofilament or multifilament), on the presence of lubrificant on the thread, and on the gauge. Tensile strength should be proportional to the diameter of a given suture material. However, most comparisons of the tensile strength of various suture materials do not normalize relative to diameter [7]

The purpose of this study is to quantitatively evaluate the failure load of several different suture materials currently employed in periosurgery.

2. Materials and methods

Tensile testing was performed to evaluate the failure load of "2", "1.5", and "1" size threads, according to European classification, corresponding to "3–0", "4–0", and "5– 0" size, respectively, according to USA classification.

The tested materials, provided by Ethicon S.p.A., were:

- silk with nominal sizes 3–0 (2), 4–0 (1.5), and 5– 0 (1);
- Ethibond with nominal sizes 4–0 (1.5), 5–0 (1);
- Ethilon with nominal sizes 4–0 (1.5), 5–0 (1);
- Prolene with nominal sizes 4–0 (1.5), 5–0 (1);
- Vicryl with nominal sizes 4–0 (1.5), 5–0 (1);
- Vicryl Rapid with nominal size 4–0 (1.5);
- no chromic catgut with nominal sizes 4–0 (2), 5–0 (1.5).

According to Italian Pharmacopeia [8] rules, thread diameter and length of each tested material were measured after extraction from sterile packaging (non-absorbable suture) or after immersion in alcohol for 24 h (absorbable sutures).

Using an optical microscope, the diameter measurements were performed on five samples of each kind of material at three different equidistant points. The measurement at each point was the average of two measurements along two perpendicular axes. The average of the five sample measurements represented the mean diameter value for each material investigated. Prescribed tensile loads for each material were applied prior to measurements.

The mean length value of each material, determined as the average of five measurements, was measured before the tensile strength tests, which were performed on five samples of each kind of material. For absorbable materials, the samples were immersed in alcohol

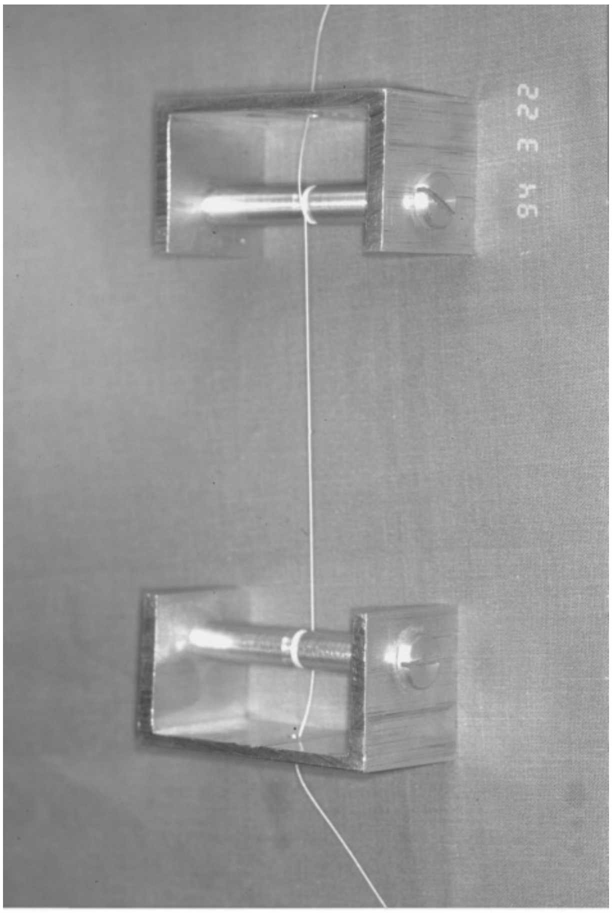

Figure 1 Device for tensile testing.

for 24 h. For each test, the suture specimen was fixed to aluminium blocks by four snug parallel wraps in order to guarantee a fixed anchoring (Fig. 1). The upper aluminium block was secured by a hook to a fixed point while a constantly increasing load at a rate of 0.1 N/s was applied to the lower block. The load was determined by direct comparison. Before being secured to the blocks, the specimen was knotted at the midpoint with a single overhand throw. In order to evaluate the failure of the sutures in the used condition, specimens knotted by a $2 \times 2 \times 1$ knot were also tested.

3. Results

The lengths, the diameters, and the values of the force to fail are given in Tables I and II for non-absorbable and adsorbable sutures, respectively.

Good correspondence between the length declared on the label and that found from direct comparison has been found.

The monofilament suture Ethilon, either for the 4–0 or the 5–0 size, and Prolene 4–0, showed diameter values in good correspondence with that declared on the label. The monofilament Prolene 5–0 had a diameter value slightly greater than the upper limit in the prescribed class 5–0. This makes for a uniform and more easily controllable diameter during the extrusion procedure. The multifilament braided sutures silk, Ethibond, Vicryl, and Vicryl Rapid were shown by the optical microscope to have diameters greater than

TABLE I Mean properties of non-absorbable sutures

	Length* (cm)	Diameter (mm)	Failure load (N)	
			Overhand throw	$2 \times 2 \times 1$
Silk				
3–0 (2.0)	74.74 (75.00)	0.282	13.42	11.91
4–0 (1.5)	45.10 (45.00)	0.243	9.05	8.26
5–0 (1.0)	75.88 (75.00)	0.201	4.88	4.35
Prolene				
4–0 (1.5)	47.20 (45.00)	0.198	10.46	9.37
5–0 (1.0)	90.64 (90.00)	0.152	6.62	6.55
Ethilon				
4–0 (1.5)	45.32 (45.00)	0.195	8.95	9.66
5–0 (1.0)	45.66 (45.00)	0.147	5.44	5.73
Ethibond				
4–0 (1.5)	44.20 (45.00)	0.249	11.75	9.28
5–0 (1.0)	77.16 (75.00)	0.190	7.57	7.03

* Length declared on label.

TABLE II Mean properties of absorbable sutures

	Length* (cm)	Diameter (mm)	Failure load (N)	
			Overhand throw	$2 \times 2 \times 1$
Vicryl				
4–0 (1.5)	68.42 (70.00)	0.237	12.41	12.73
5–0 (1.0)	68.62 (70.00)	0.183	8.28	8.11
Vicryl Rapid				
4–0 (1.5)	73.64 (75.00)	0.247	7.98	7.02
No chromic catgut				
4–0 (2.0)	74.94 (75.00)	0.234	9.15	10.89
5–0 (1.5)	76.04 (75.00)	0.182	5.91	7.22

* Length declared on length.

those declared on the company label. This means a less uniform and less easily controllable diameter during the extrusion procedure. According to Pharmacopeia rules,

- the 3–0 silk corresponds to "2.5" instead "2.0" diameter;
- the 4–0 silk, Ethibond, Vicryl, and Vicryl Rapid correspond to "2.0" instead "1.5" diameter;
- the Prolene 5–0 corresponds to "1.5" instead "1.0" diameter;
- the 5–0 Ethibond, and Vicryl correspond to "1.5" instead "1.0" diameter;
- the 5–0 silk corresponds to "2.0" instead "1.0" diameter.

The no chromic catgut sutures showed good diameter regularity that matched what was declared on the company label. It has to be emphasized that the No chromic catgut sutures have a different correspondence between American and European classifications: the 4–0 and 5–0 correspond to "2.0" and "1.5", respectively.

With regard to failure load, all the sutures examined in this study conform to Italian Pharmacopeia tolerances. Owing to the greater measured diameters at all gauges of the great majority of the examined sutures, failure loads are, in general, remarkably superior to

TABLE III Comparison of mean failure load values

	Diameter (mm)	Failure load (N)
Prolene 4–0 (1.5)	0.198	10.46
Ethilon 4–0 (1.5)	0.195	8.95
Vicryl 5–0 (1.0)	0.183	8.28
Ethibond 5–0 (1.0)	0.190	7.57
Catgut 5–0 (1.0)	0.182	5.91
Silk 5–0 (1.0)	0.201	4.88

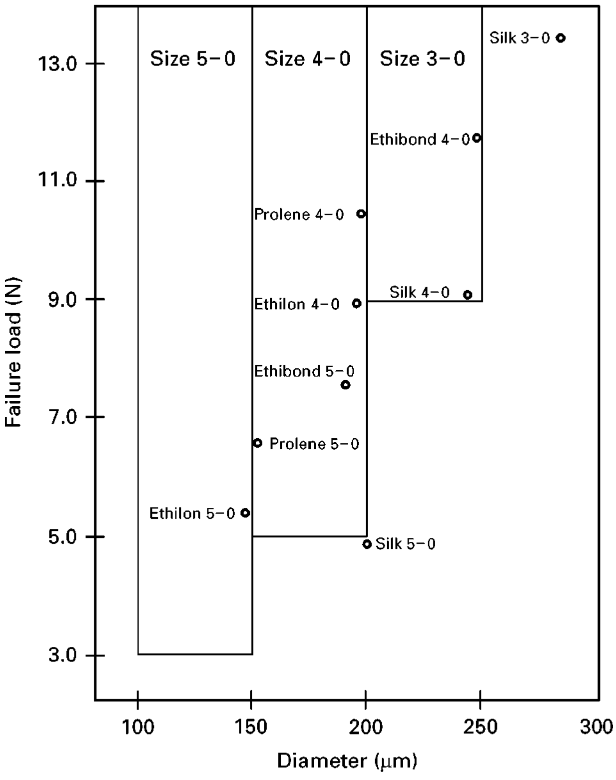

Figure 2 Mean values of the diameter and failure load of the tested non-absorbable sutures with reference to the Italian Pharmacopoeia tolerances.

the lower limits prescribed in the Italian Pharmacopeia. To compare the failure load of the tested sutures it is necessary to refer to restricted diameter class.

Comparison on the basis of effective diameter class in the range 0.182 to 0.201 mm of the tested sutures is summarized in Table III.

Figs 2 and 3 show the mean values of the diameter and failure load of the tested sutures with reference to the Italian Pharmacopeia tolerances.

4. Discussion

Due to the limited research on sutures used in dentistry, some of the most important properties of suture materials have been investigated in collaboration with Ethicon S.p.A., Pomezia (Italy), one of the more known and trustworthy producer companies. The investigation has pointed out very good behaviour of the tested sutures relative to rupture load. Relative to the diameter, some differences have been found from what was written on the suture labels. These differences should be known to the periodontist to give improved awareness of the surgical procedure.

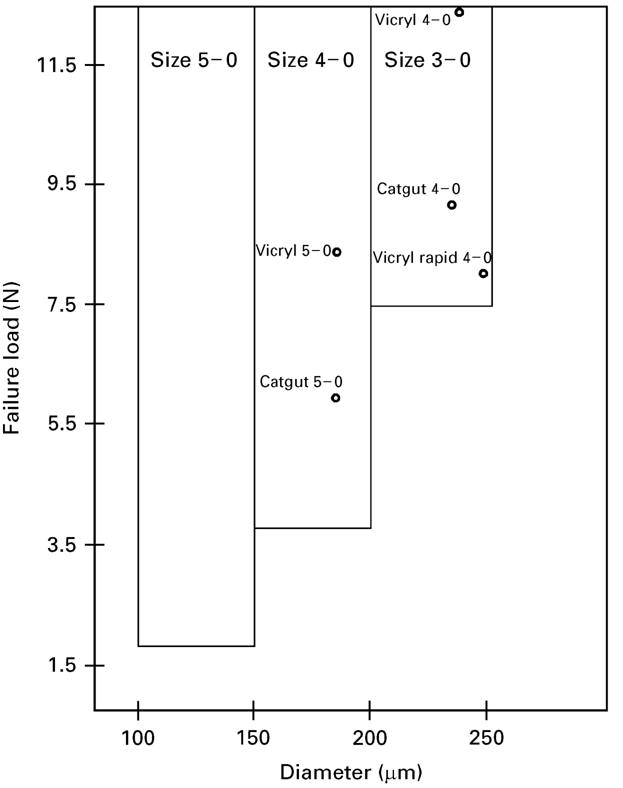

Figure 3 Mean values of the diameter and failure load of the tested absorbable sutures with reference to the Italian Pharmacopoeia tolerances.

Only Ethilon 4–0 and 5–0, Prolene 4–0, no chromic catgut 4–0 and 5–0 are in good agreement with Italian Pharmacopeia tolerances, either for diameter or for failure load.

Considering silk, which is the most widely used suture in dentistry, as reference material, a comparison on the basis of Table III gives the following results:

- Prolene presents a rupture load that is more than double that of silk, and Ethilon presents a rupture load that is almost twice that of silk.
- Vicryl and Ethibond present a rupture load that is definitely superior to the values for silk.
- No chromic catgut presents a rupture load superior to that for silk.

The rupture load for threads knotted with a $2 \times 2 \times 1$ knot is, for almost all the tested sutures, slightly lower than the value for threads with a single overhand throw placed at the midpoint.

Prolene and Ethilon are, moreover, sutures that present a regular, uniform diameter since they are more easily controllable during the production procedure.

The multifilament materials Vicryl, Ethibond, silk and catgut present a less regular and uniform diameter since they are less controllable during the production procedure. In fact the diameter determined from optical microscope measurements indicates a larger size than that declared by the producer firm.

TABLE IV Characteristic failure load values

	Mean failure load (N)	Characteristic failure load (N)
Silk		
3–0 (2.0)	13.42	11.94
4–0 (1.5)	9.05	6.79
5–0 (1.0)	4.88	4.08
Prolene		
4–0 (1.5)	10.46	8.51
5–0 (1.0)	6.62	5.71
Ethilon		
4–0 (1.5)	8.95	6.90
5–0 (1.0)	5.44	2.45
Ethibond		
4–0 (1.5)	11.75	10.80
5–0 (1.0)	7.57	7.33
Vicryl		
4–0 (1.5)	12.41	10.40
5–0 (1.0)	8.28	3.92
Vicryl Rapid		
4–0 (1.5)	7.98	6.57
No chromic catgut		
4–0 (2.0)	9.15	5.15
5–0 (1.5)	5.91	3.44

Based on probability and statistics, the characteristic failure load for any suture material can be calculated on the basis of experimental results from a large sample size. Since the sample size is currently small, as indicated in Pharmacopeia rules, a semi-probabilistic method included in many structures codes can be employed to determine the characteristic failure load. The value of the characteristic load is derived using the formula:

$$P_C = \bar{P} - ks$$

where P_C is the characteristic failure load (the 0.05-fractile of the normal distribution), $\bar{P}$ is the mean failure experimental load value, k is a factor dependent on the sample size n and the risk level, and s is the standard deviation. In the present case, the calculated characteristic values, for $n = 5$ and $k = 4.21$, and the mean values are indicated in Table IV.

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