Mechanical Tests
Compression, Torque, Flexure and Fatigue

PURPOSE

This involves determining the mechanical properties of AVINENT dental implants, specifically the fatigue strength of these implants according to standard UNE-EN ISO 14801, torque strength and compression strength.

MATERIALS AND METHODS

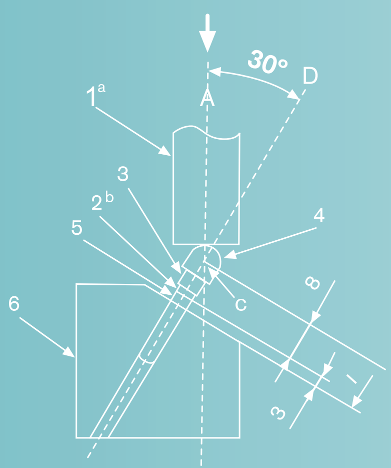

Figure 1.

Figure 2. 3.3 x 13 mm AVINENT Implant with hemisphere attached.

Description of the Implant Tested

AVINENT implants with a diameter of 3.3 x 13 mm long were used in performing fatigue, compression and torque tests. It was decided to use the 3.3 x 13 mm implant for the mechanical tests because mechanically it is the weakest implant in the entire range due to its small dimensions and because it has the finest thread pitch, which increases the concentration of stresses.

a. Fatigue Tests

The fatigue test consists of simulating the functional load on the body of the dental implant and the components of its prosthetic portion under the worst possible conditions.

In order to comply with the testing scheme required under the UNE EN-ISO 14801 standard (fig. 1), the implants used in these fatigue tests had a hemispheric member with a radius of 2.5 mm mounted on their exposed end to avoid lateral stresses in the test. A sample of the implant-hemisphere system may be seen in figure 2.

In performing these tests, an MTS Bionix 858 tensile-compression testing machine specially designed for use with biological materials was used, which also can be used for performing fatigue and torque tests. This machine was equipped with an MTS 2.5 KN load cell. The equipment was controlled through connection to a PC equipped with the TestStar® software package. The equipment described may be seen in figure 3.

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*(1) **Scientific committee of AVINENT Implant System S.L.**, A. Cortina, C. Vendrell, E. Falcó, J. Serra*
*(2) **CREB**: A. Mestre*
*(3) **CTM**: J. Caro, Ma D. Riera, J. M. Prado*

Figure 3. MTS Bionix 858 tensile / compression testing machine.

Figure 4. Fastening holder for dental implants.

Figure 5. Implant with torque testing device.

Test mounting may be seen in figure 4. Application of the load was performed with a flat punch. The angle of inclination of the implant with respect to the load application axis was 30°. The implants were fastened at a distance of 3 mm from the apex from the level of the nominal bone, which in this case is the treated surface of the implant. The distance called 1 in the diagram in figure 1, from the center of the hemisphere to the fastening plane, was 11 mm.

Both the holder for the implant and the punch were made from steel with an elasticity modulus of 200 GPa. The implant was fastened to the holder base by a tightening plate.

The hemispheric load member made of medical grade Ti was fastened to the implant with a screw of this same material, which will be marketed along with the implants.

The load applied in these tests was sinusoidal, and it ranged from an established maximum load to 10% of that same load. Frequency for all tests was 15 Hz.

These fatigue tests were performed under ambient conditions at a constant temperature of 24° C.

b. Torque Tests

In performing the torque tests, a fixture was screwed to the exposed end of the dental implants (fig. 5) to determine the torque necessary to strip the hex head of the implant.

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Figure 6. Tohnichi Torque Meter.

c. Compression Tests

Compression tests were performed on the Bionix 858 machine described in part a). In this case, two parallel flat surfaces were used as jaws for the test. The implant was compressed longitudinally until it ruptured.

RESULTS

Fatigue Tests

Maximum strength of the implants was initially determined by performing a static flexure test at 30° until the implant ruptured. Piston travel rate was 1 mm/min. Six tests were performed and then a calculation was made of average strength from all tests. Maximum strength results for these implants are shown in table 1.

Fatigue tests were performed by applying a maximum flexural load calculated as a percentage with respect to the maximum flexural load resisted and a minimum load of 10% as stipulated by the UNE-EN ISO 14801 standard. Thus, one test

Table 1. Flexure tests results at 30°.

Test	1	2	3	4	5	6	Size
Fracture Strength	1011 N	1049 N	1009 N	986 N	947 N	1023 N	1004 ± 34 N

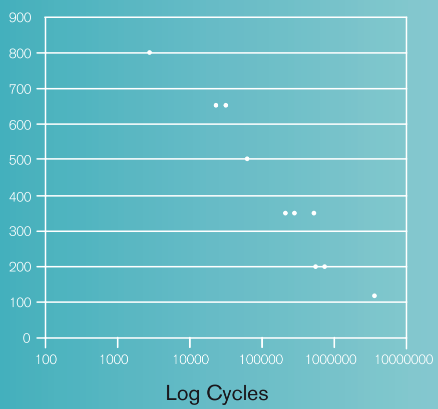

Figure 7. Resulting fatigue curve.

at 80% of the maximum flexural load, two tests at 65%, two at 50%, three at 35%, two at 20% and three tests at 12% of the maximum flexural load were performed.

The graph in figure 7 shows the trend in fatigue results in a clearer fashion. This graph represents the maximum force applied in each test with respect to the number of cycles resisted by the implant.

The nominal moment of curvature for maximum load duration may be calculated by this formula:

$$M = 0.5 \times F \times l$$

Where F is the load applied at maximum duration, in this case 120 N; «l» is the distance from the fastening plane to the center of the load, in this case 11 mm.

Therefore, the moment of maximum curvature is equal to:

$$M = 0.5 \times F \times l = 6.6 \text{ N·cm}$$

Concerning fracture location, all fractured implants; that is, all implants tested at over 120 N maximum load, ruptured in the area close to the fastening plane.

Torque Tests

Six implants were tested for torque. The test consisted of progressively increasing the torque applied until the hex head of the implant became stripped.

The results obtained in torque tests may be observed in table 3.

Table 2. Torque strength results for implants.

Test	1	2	3	4	5	6	Size
Stripping Strength	1.6 Nm	1.6 Nm	1.8 Nm	1.4 Nm	1.8 Nm	1.6 Nm	1.6 ± 0.2 Nm

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Compression Tests

Three compression tests were performed to determine the maximum strength of the implants. Figures 8, 9 and 10 show the graphs obtained from these tests. It may be observed that maximum implant strength is attained just before rupture. Table 4 shows fracture strength results for the implants tested, as well as their average and typical deviation.

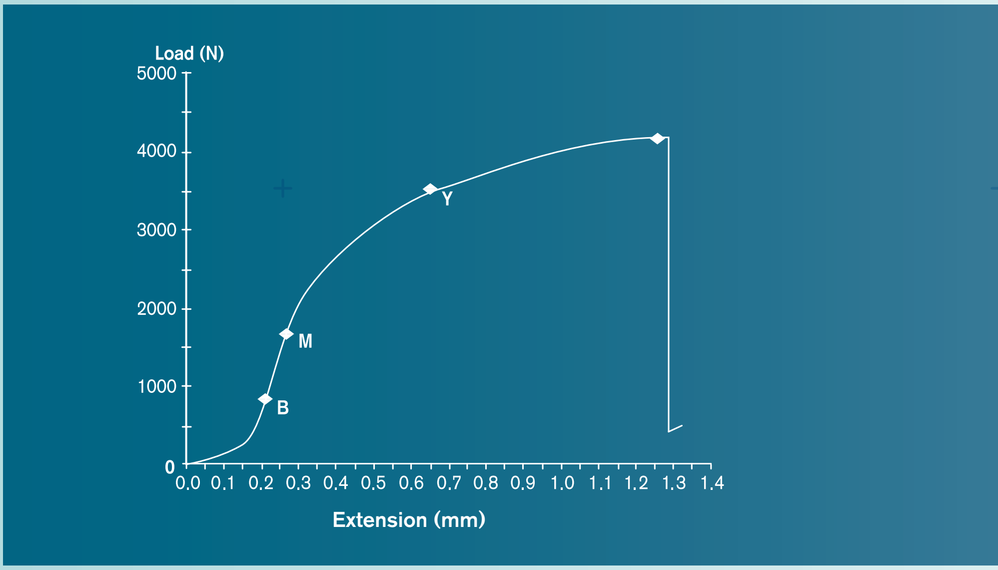

Figure 8. Compression graph for specimen 1.

CONCLUSIONS

The 3.3 x 13 mm AVINENT implant studied showed a maximum flexure strength of 1004 ± 34 N at 30°.

The load from which the 3.3 x 13 mm AVINENT implant provided infinite fatigue life is approximately 120 N; that is, 12% of the maximum flexural load resisted at 30°. The maximum moment of curvature of the implant was determined to be 6.6 N·cm.

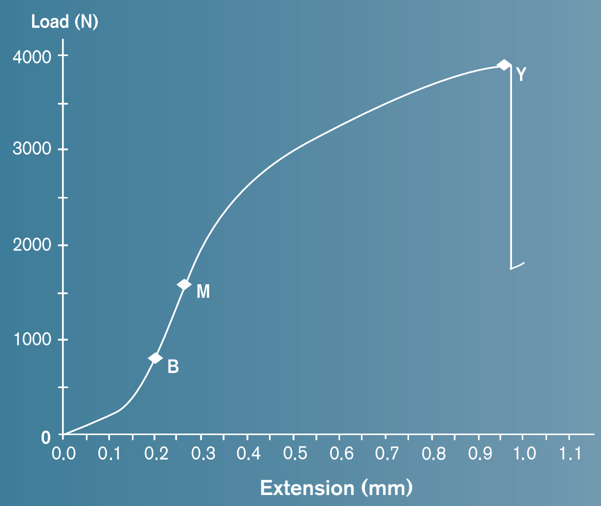

Figure 9. Compression graph for specimen 2.

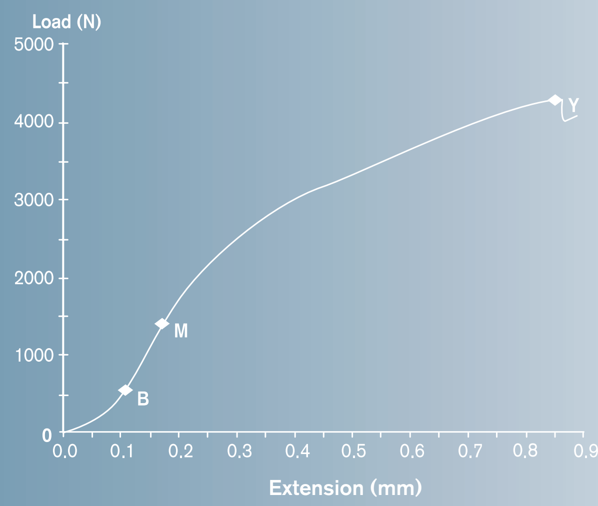

Figure 10. Compression graph for specimen 3.

The curve described by the results of fatigue tests shows normal behavior for metallic components.

Torque strength of the implants before stripping the hex head of the implant is 1.6 ± 0.2 N·m.

The longitudinal compression strength of AVINENT 3.3 x 13 mm implants is 4112 ± 197 N.

Table 3. Compression test results.

Test	1	2	3	Size
Fracture Strength	4169 N	3893 N	4275 N	4112 ± 197 N