Titanium-nickel (Ti-Ni) is a highly elastic metal alloy with a number of dental applications. A study of the mechanical behavior of an experimental Ti-Ni clasp for removable partial dentures was recently conducted. (See Titanium-nickel Alloy Clasps for Removable Partial Dentures, inside.)

Biomechanics in Prosthodontics

Biomechanics is the application of mechanical principles to biological systems. Prosthodontists place artificial substitutes for damaged and missing teeth in patients' mouths on a daily basis, and these artificial substitutes must function effectively in a living environment. In vitro biomechanical studies are useful because they evaluate the behavior of dental materials under controlled conditions, attempting to predict the clinical behavior of the materials studied. This issue of Prosthodontics Newsletter reviews several in vitro biomechanical studies related to prosthodontics.
Titanium-nickel Alloy Clasps for Removable Partial Dentures

A retentive clasp for a removable partial denture (RPD) is designed to engage an undercut on the abutment tooth. The clasp must flex during insertion and removal of the RPD, and incomplete elastic recovery of the clasp after repeated flexure could result in loss of retention of the RPD. Titanium-nickel (Ti-Ni) alloy is highly elastic and resists permanent deformation after repeated bending. Because of its elastic properties, Ti-Ni may be a suitable alloy for cast RPD clasps.

Kim et al from Kangnung National University, South Korea, investigated the retentive properties of cast Ti-Ni circumferential clasps compared with the performance of cast cobalt-chromium (Co-Cr) clasps, cast Type IV gold-alloy clasps and wrought Co-Cr-Ni wire clasps. A test model was made, and 98 experimental clasps were fabricated. Variables included depth of undercut (0.25 mm and 0.75 mm) and width of the cast clasps (0.8 mm and 1.4 mm). All clasps were examined radiographically to detect internal defects.

The force in newtons required to remove the clasps was measured on a universal-testing machine. The clasps were then inserted and removed by a masticatory simulator for a cycle of 500 times. The insertion-removal cycle was repeated 10 times, and retentive force was measured after each of the 10 cycles (Figure 1).

Ti-Ni clasps experienced negligible loss of retention throughout the experiment. The retentive capacity of all cast clasps was gradually reduced as a result of repeated flexure of the clasps, although loss of retention for the wrought wire clasps was relatively minor. The most dramatic loss of retention occurred with the Co-Cr clasps. The endpoint retentive values were similar for all clasps, and clasps engaging 0.25 mm undercut were less retentive than those engaging 0.75 mm undercut. Radiographs revealed porosities in 7 of the Ti-Ni alloy clasps.

Comment

While this study suggested that Ti-Ni clasps possessed superior elastic recovery compared with the other clasp materials, the end results were similar for all clasps after cyclic flexure that simulated 3 years of clinical use.

Co-Cr is the most commonly used alloy for clasp fabrication. Initially the Co-Cr clasps were most retentive, but they gradually lost much of their retention over time. This property of Co-Cr clasps has clinical advantages. When an RPD is initially inserted, increased retention can facilitate the patient’s adaptation to the prosthesis. Once the patient becomes accustomed to the RPD, less retention would be required.

Also, the internal porosities observed with many of the Ti-Ni clasps are of concern. Previous studies have reported that Ti alloys are difficult to cast, and castings commonly contain porosities. These internal defects could result in fracture of the clasps in service.


Abutment Screw Loosening with Externally Hexed Implants

Screw loosening is a complication that can occur with implant-supported single crowns. A tightening torque of 32 Ncm for the abutment screw has been recommended for externally hexed implants to produce a preload that will reduce the potential for screw loosening. A study of the effects of laterally directed loads on the stability of screw-joint preload was conducted by Khraisat et al from Niigata University, Japan.

Three groups, each containing 5 externally hexed Mark IV implants with CeraOne abutments (Nobel Biocare AB) and an experimental cemented superstructure, were formed. Abutment screws were tightened to 32 Ncm. One group was subjected to cyclic loading of 50 N applied perpendicular to the
long axis of the implant and centered at the hex. The second group received a similar cyclic load applied 4 mm from the center in a loosening direction. The control group was not loaded.

Reverse torque was measured before and after loading, and the difference was calculated. The mean reduction in reverse-torque value for the centrally loaded specimens was 4.26 N cm, and this reduction was significantly different from the other 2 groups. Mean reductions for the eccentrically loaded and nonloaded groups were 0.92 N cm and 0.38 N cm, respectively, and were not significantly different from each other.

**Comment**

The authors did not encounter any loose screws in the study, suggesting that sufficient preload was maintained for all groups. The authors offered an explanation for the differences in reverse-torque values for the 2 loaded groups, suggesting that off-center loading caused binding at the corners of the mated hexagonal components of the abutment/implant connection that protected the screw from bending. When the assembly was centrally loaded, binding at the hexagonal corners did not occur, allowing micromovement of the components with bending and fatigue of the screw.

In the mouth, most of the cyclic loading would occur off-center; therefore, the off-center loading would more likely simulate clinical conditions. The cyclic loads used in this study were lateral in nature and relatively low, simulating only 40 months of intraoral function. Most authorities on implant-supported prosthodontics suggest an occlusal scheme that avoids or reduces non-vertical forces on the implants. Nevertheless, lateral loads in vivo will often exceed the loads used in this study. The results of longer loading cycles or heavier loads are unknown.


**Fracture Resistance of A New Zirconia Post**

All-ceramic restorations have become popular for the restoration of anterior teeth. A pulpless anterior tooth often requires a post and core to support and retain an artificial crown. Traditional posts are metallic; however, some dentists prefer to use nonmetallic posts with all-ceramic crowns because of esthetic concerns. Posts made of zirconia have been marketed as “esthetic” posts for all-ceramic crowns.

One problem with commercially available zirconia posts is related to retention of the core material to the post. A new zirconia post was designed by Oblak et al from the University of Ljubljana, Slovenia. This post contains an irregularly shaped coronal portion to augment the retention of the core reconstruction (Figure 2).

These zirconia posts are made from high-strength ceramics, but grinding or air abrading with aluminum oxide particles can alter their physical and mechanical properties. The authors investigated the effects of grinding and air abrading on the fracture resistance of their newly designed post system. Posts of 2 different diameters, 1.3 mm and 1.5 mm, were studied. One group of posts was ground with a diamond stone. A second group was air abraded with 110-μm aluminum oxide particles, and a third group (controls) received no surface treatment.

The posts were luted in root-form artificial canals with the use of the Clearfil bonding system (Kuraray) and Panavia 21 resin cement (Kuraray). The cemented posts were loaded on a universal-testing machine at an angle of 45° until fracture occurred.

With the thicker posts, mean fracture loads were 518.4 N for the ground specimens, 993.6 N for the air-abraded specimens and 622.7 N for the controls. For the 1.3-mm diameter posts, mean loads were 385.9 N for the ground specimens, 627.0 N for the air-abraded specimens and 451.2 N for the controls.

Although the ground posts recorded lower fracture resistance...
compared with the controls, this difference was statistically significant for the thicker posts only. Air abrasion increased the fracture load significantly for both diameters.

Comment
In this study, fracture resistance was primarily related to post diameter, and grinding the posts with a diamond stone substantially reduced the strength of the posts. Air abrasion with aluminum oxide improved the strength of the posts.

Although wider-diameter posts were stronger, these wider posts would require additional removal of radicular tooth structure in the root canal to accommodate them. Many studies of restored endodontically treated teeth have concluded that excessive reduction in the thickness of radicular dentin along the root canal compromised the fracture resistance of the root. Therefore, removal of tooth structure would allow the use of a wider and stronger post, but at the expense of weakening the root of the tooth.

All posts in the study fractured at their necks. If a zirconia post fractures clinically, it will presumably fracture with a fracture mode similar to that seen in this study—at the neck of the post where it exits the root canal. Because of its extreme hardness, this post would likely be impossible to remove from the root canal, rendering the tooth nonrestorable.

Many factors must be considered when selecting a post system. If a zirconia post is used, grinding of the post should be avoided, and airborne-particle abrasion as conducted in this study would potentially improve the strength of the cemented post.


Simulated Occlusal Forces and Stress Distribution in Dental Implant Screws

Another study related to screw biomechanics, conducted by Alkan et al from Marmara University, Turkey, used finite element analysis (FEA) to evaluate stress distribution in preloaded implant screws. Three abutment-implant joint systems were simulated with the FEA:

- Externally hexed screw-joint system (Brånemark standard abutment; Nobel Biocare);
- 8° Morse-tapered abutment for cemented crown (solid abutment; ITI Straumann AG); and
- 8° Morse-tapered plus internal octagonal screw-retained abutment (synOcta abutment; ITI Straumann AG).

The simulated, preloaded, implant-supported crowns were loaded with 3 static loads (10 N, horizontally; 35 N, vertically; and 70 N, obliquely). After simulated horizontal loading, stresses increased for all 3 models. After vertical and oblique loading, stresses decreased at the abutment screws and at the prosthetic screws for the Brånemark externally hexed abutment and the ITI internal octagon abutment, with the exception of the prosthetic screw for the internal octagonal abutment when loaded obliquely. Stresses increased in the ITI solid abutment after both vertical and oblique loads.

Comment
Decreases in stresses suggest reduction in the clamping forces generated by the screws with the potential for screw loosening. Increases in stresses beyond the yield strength of the screw could cause the screw to fracture. Neither situation is desirable.

The authors indicated that the results of this study did not demonstrate changes in stress values likely to produce screw fracture or loosening. Nevertheless, higher occlusal forces could occur clinically, especially as a result of parafunctional habits, and might produce different results.