9.3.1.3 **Schubiger Screwblock** (Short pattern)\(^1\) (Figure 9.30)

These screws are designed for bar construction, when no secondary coping is desired. The secondary coping is eliminated by the use of a sleeve, to which the bar is soldered, and which is locked onto a patrix with threaded post (identical to the Gerber-patrix soldering base), by a cap nut. The heights of the short Schubiger are 2.80mm and 3.05mm. The outer diameter is 3.00mm and 3.20mm.

The system is ideal for divergent roots (see Figure 9.32) and for abutments for bar fixation, which may need to be changed to single attachment fixation in the long term (by replacement with a Gerber attachment). The disadvantages are that the system has excessive bulk when added to the top of the root cap. Height reduction may be more easily achieved by a secondary coping technique.

9.3.1.4 **Schubiger Screwed Anchor** (659A and 659)\(^1\)

A longer form of the same screw block which is suitable for a screw through the appliance from the occlusal surface. Heights are 7.00mm and 8.00 mm and the widths 3.00mm and 3.20mm.

9.3.1.5 **Hruska Tapered Anchor with Screw** (709A and C)\(^1\) (Figure 9.31)

This attachment is mainly designed for use with telescoping crown assemblies or screwed crowns to root caps. However, it can be used as a long coping and bar configuration when the abutments have non parallel canals. The heights of the Hruska anchors are 3.60mm (A), 4.30mm (709), both of which have offset screws and 4.00mm (709C) which has a vertical screw.

AUXILLARY ATTACHMENTS

Figure 9.30: The Schubiger Screw Block.

Figure 9.31: The Hruska Tapered Anchor.
Figure 9.32: The Use of a Schubiger Screw Block for Non-Parallel Abutments
9.3.1.6 **V.K. Double Screw**

A system of posts which provide a cylindrical anchor and screw which can be used in a similar way to the Schubiger Screwblock once a secondary coping is stabilised.

9.3.2 **Pawl Connectors.** These are used to increase the retention of bar units being either soldered or cast into a bar. The action of the pawl connector is to provide a spring loaded catch placed horizontally to the path of insertion of the denture. It provides a positive click when the prosthesis is fully into place. This attachment should only be used for a bar unit, as any rotational allowance negates the action of the pawl connector. The pawl connector may prolong the life of the bar, as wear only occurs on the replaceable parts of the attachment. Attachments include:

9.3.2.1 **ASC-52 Spring Rest** (Figure 9.33)

A short pawl connector 3mm in length suitable for Class III-VI applications, anterior and posterior applications. It has a simple assembly compared to other units and has a resilient action horizontally. It is adjustable by the pawl screw onto the spring and should be replaced 6 monthly. The components are interchangeabe and replaceable and are made in a variety of metals.

9.3.2.2 **Ipsoclip** (Figure 9.34)

A horizontal pawl connector for bars and their riders in two different designs; one for access to the plunger for servicing from the

Figure 9.33: The ASC-52 Spring Rest

Figure 9.34: The Ipsoclip
back and one for servicing from the plunger side. The attachment is either 2.5mm or 2.6mm long and tapered from 2.9mm to 2.4mm in diameter.

i) The first type is suitable for placement in the bar of the fixed unit. The screw is situated opposite the stud and at the wider end. The attachment should be placed so that the screw is accessible, i.e. pointing lingually or palatally. This type is slightly longer than the second type, being 2.6mm. It consists of a tapered housing with the opening for the stud in the narrow end. Then the stud, with a guide behind for the steel coil spring, backs it. This is opposed by the matrix consisting of a rear opening bayonet lock with screwdriver slot.

The model designed for 'cast onto' in ceramicor, has a retention ridge halfway along the housing. The soldering housing is in elitor and is smooth.

ii) The second type is designed to be incorporated in the removeable segment has the configuration reversed. It is slightly shorter (2.5mm).

9.3.2.3 The Pressomatic (Figure 9.35)

A pawl connector similar to the ipsoclip and functioning in a similar manner. It is 2.9mm long, making it more difficult to place than the ipsoclip and 2.6mm wide. A neoprene cushion provides the spring behind the plunger.

9.3.2.4 The Mini Pressomatic (Figure 9.36)

This is a much narrower but quite wide pawl connector. It is 2.45mm long including the button and 3.2mm wide. Rather than neoprene, a stainless steel spring is used to provide retention. This attachment can also be converted to provide a screw bolt to fix a prosthesis in place if needed.

1. Metaux Precieux, Neuchâtel, Switz.
The *Presso-Matic* consists of the following parts:

- **Sleeve with internal thread**
- **Plunger**
- **Neoprene cushion**
- **Locking screw**

![Figure 9.35](image)

The *Mini-Presso-Matic* consists of the following components:

- **Matrix housing** (can be cast on)
- **Plunger (replaceable)**
- **Stainless steel spring (replaceable)**
- **Hollow screw (replaceable)**

![Figure 9.36](image)
CHAPTER 10

MAGNETIC ATTACHMENTS USED IN OVERLAY DENTURES

10.1 History

The use of magnetic repulsion in dentistry was first described by Winkler and Pearson (1967) when 'Alnico' bar magnets (aluminium, cobalt and nickel alloy magnets) were used in dentures to repulse each other in an attempt to seat the dentures in place. The increase in seating force when the dentures were in contact, caused an increase in ridge resorption and when the jaws were apart, the seating forces were virtually non existent. Mutual attraction of magnets was described in some literature by Thompson (1964), Thomas and Freene (1970), Jarid (1971) and Frederick (1976) in conjunction with post surgical prosthetics and for complete denture cases by Behrman (1960), Toto et al. (1962), Coghan and Hartz (1973) and Connor and Svare (1977). Some authors, e.g. Behrman (1960) found success and others, e.g., Connor and Svare (1977) found failure, the mutual attraction of an implanted magnet causing exfoliation. Obviously retention devices for dentures needed to be in contact, not separated, to allow greatest application of the forces involved and to prevent the potential problems of unwanted movement.

Cobalt Samarium (Co₅Sm) magnets representing a new breed of magnets developed in the late 1960's (Becker, 1970), brought new possibilities to dentistry. Rare earth elements in alloys with cobalt, provide magnets far more powerful than the original alnico magnets originally used. One of the best "performers" is the Cobalt Samarium
magnet, which has high "intrinsic coercivity" or permanence, being 5 times greater than CoPt magnets and 10 times greater than the best Alnico magnets. Also they can be made to be very short yet still retain a high magnetic field, i.e. even though the north and south poles are close, the field still can be maintained.

Another commercially available Rare Earth alloy magnet contains neodymium, iron and boron, which appears to have even greater magnetic properties, but which has not received classification for intra oral use by the American Food and Drug Administration. Toxicity studies have been carried out on these materials by Haley (1965) and Tsutsui et al. (1979), which have cleared the SmCo₅ for use in the mouth. Separate studies have detailed the toxicology of cobalt by Underwood (1958) and Heath et al. (1971) and samarium by Comar et al. (1962), Sax (1975), De Bruin (1976) and Martindale (1977).

Consequently these magnets were described as being used in dentistry from 1976. The miniature nature of the magnetic components made adaptation in orthodontics (Kawata and Kateda (1977) and Kawata et al. (1978)), in prosthodontics, from Yoshida and Ushita et al (1979), Tamura et al. (1978), and Moghadan et al. (1979) and in sectional denture use (Yoshida, 1979).

However, although toxicology studies show there may be no danger from the elements in these magnets, there may be some doubt as to the biological effects of long term magnetic fields on tissue, as discussed by some authors, including Barnothy (1964, 1969), Roth (1968) and Becker (1970). Thus in 1977, Gillings devised a magnetic attachment system,¹ which would virtually eliminate the external magnetic field from his

1. University of Sydney patent.
magnetic attachment. Although most studies undertaken to establish tissue effects were in the order of 100-1000 millitesla, some reports claimed effects at 8 millitesla. Open field magnets, as used in the Japanese studies, can produce fields close to 30 millitesla at the root face. When the magnets are paired with opposite poles adjacent and fitted with ferromagnetic end plates, or "keepers" (initially of soft iron and later of ferromagnetic stainless steel), the magnetic flux is contained within this system. This reduces the lateral field by a factor of 75-200 times, i.e. the field next to the root face would only increase from 0.05 millitesla (the earth's magnetic field) to a maximum of 0.1 millitesla, when the magnets are in contact with the keepers. Hence, the closed field magnetic retention unit was developed and discussed by Gillings (1977, 1978, 1979, 1981) (Figure 10.1).

**Magnetic Retention**

Retention is dependent upon keeper thickness, the size of the air gap and the size of the magnet.

1. **Keeper Thickness.** As determined by breakaway load tests of a standard sized magnet unit against various base keeper thicknesses, it was found that 1.2mm keepers provided maximal retention in stainless steel - an increased thickness of keeper provides no improvement in retention and possibly difficulties in positioning on the root faces (Figure 10.2).

2. **Air Gap.** An air gap between the split poles of the magnet unit is essential to enable the magnetic flux to pass through the keepers (Figure 10.3).

Thus it was found that no significant increase in retention
**MAGNETIC FIELD STRENGTH OF Co/Sm MAGNETS**

**EARTH'S MAGNETIC FIELD:**
0.33 - 0.66 milliTesla
(0.3 - 0.6 gauss)

**OPEN FIELD**

**CLOSED FIELD**

**DISTANCE:**

**Figure 10.1:** Graph Comparing Flux Density of Magnetic Designs over Distance

**BREAKAWAY LOAD vs KEEPER THICKNESS**

**Co/Sm MAGNETS**
(s/s caps)

**Br. LOAD (gms)**

- 200
- 100

**KEEPER THICKNESS, K.T. (mm)**

1.0 - 2.0

**Figure 10.2:** Graph Demonstrating the Criteria for a Keeper Thickness of 1.2mm
occurred after 0.8mm of separation. This distance was adopted in the magnetic retention unit to limit the size of the retention unit.

3. **Magnet Size.** On the basis of statistical analysis of mean root face diameters (Gillings, 1981), a magnetic keeper of 5 x 3.2mm was found to be able to be fitted to most anterior and premolar teeth, excepting some maxillary lateral incisors and mandibular central and lateral incisors. Other teeth would need either cast or cement-on keepers.

Consequently the magnet size of the original University of Sydney patent unit was developed to fit onto a standard keeper, i.e. two cylinders each 3.2mm in diameter with an 0.8mm segment cut from each to function as the air gap. Height was determined by the fact that no substantial strength is gained by making the magnet more than half the diameter in height. Thus the magnet height is 1.5mm in the Gillings retention unit and this is topped by a keeper of 1.2mm.

**Other Factors Affecting Retention**

4. **Corrosion.** Because of the manufacturing process, whereby magnets are made by compressing fine particles of alloy in a strong magnetic field, the magnets tend to corrode under use. Pursuant to this, magnetizable stainless steel caps 0.25mm thick are fitted to the face of the magnets, which hold the magnets in place and prevent wear and corrosion for up to 10 years. The magnetizable alloy shows no significant reduction in retentive strength, even with this quite significant thickness of metal.

Consequently, the total height of this retention unit is approx. 3.0mm, being the sums of heights of all three components.
Figure 10.3: Graph Showing the Effect of a Variance in the Air Gap on Retention

Figure 10.4: A Graph Comparing the Magnetic Attraction of Different Magnet Systems
5. Retentive Force After Initial Separation

The arrangement of split pole magnets causes a rapid drop in retentive (or attractive) force on separation of the unit and the keeper in comparison to an open field paired magnet arrangement. However, the initial breakaway load for similar sized magnets is almost twice as much in the case of the split pole system. Consequently, the retentive force is still considerable as long as the units are in close proximity, i.e. less than 0.3mm (Figure 10.4).

The description of the magnetic properties of the closed field system devised by Gillings (1979) has led to further development of magnetic attachments for use on overlay dentures. The original design did develop problems due to the bulk of the attachment and corrosion (Gillings, 1987). Manufacture of the component parts to incorporate protective stainless steel alloy end plates was extremely difficult and not entirely faultless. Eventually the endplates would work loose and corrosion and fracture of the magnets would ensue, resulting in loss of magnetic retention. A new system of magnet orientation is now being used which overcomes the previous problems, but because it is commonly applied in many magnets used in domestic and industrial situations, it is not patentable.

The new system involves the use of a single hemispherical magnet, with keepers on either side being used against the keeper as shown in Figure 10.5. This system is still a closed field system and actually produces more retention than the paired magnet system previously used.

The reason could be explained as the comparison of the magnetic fields (Figure 10.6). In effect the field strength lines have less distance to travel and thus provide a greater strength of retention (Gillings, 1987).
Figure 10.5: The Gillings' Mini Magnet Dimensions

Figure 10.6: Comparison of Magnetic Fields in Different Magnet Systems
The corrosion problem has also been overcome by the use of a stainless steel tube into which the magnet is packed which completely encloses the magnet once the side plates are glued into position.

Jackson in 1966 described his own magnetic retention system, which is based on this same design but is larger and thus has more retention. He has tested a number of shapes and has found the differing properties of each. In comparison of 9 different rectangular magnetic assemblies, it was found that the assembly now currently being used in parallel steel plates around the magnet, had the highest holding power of all the different types. However, it does have the lowest reaching power of all the magnet types (this may be an advantage to reduce tissue effect, but is a disadvantage to reseating). Also, it was found that elimination of the external magnetic flux was not as effective. However, because of the ease of manufacture, an improved size/retention ratio and corrosion control, this design seems the most sensible.

Magnets Currently Available for Use in Overlays

1. **The Dyna Attachment** (Figure 10.7)

   An open field magnet 2.6mm high and 4.5mm in width. Uses a rare earth cylinder magnet with a stainless steel cover cap. The system has no control over external magnetic flux and also has only fair retention for its size (see Table 1, page 129).

2. **The Magnedent Attachment** comes in 3 sizes (Figure 10.8):

   The Magnedent small - 1.9mm high, 4.5mm wide

   2. Indenco, Inc., Flanders, New Jersey.
Figure 10.7: The Dyna Attachment
The Magnedent medium - 2.1mm high, 5.0mm wide
The Magnedent large - 2.4mm high, 5.7mm wide.
This is a cylindrical magnet enclosed in a stainless steel cup, which creates a closed field system but has only low retentive figures (see Table 1, page 129). This attachment also is enclosed by a stainless steel covering cap to protect against corrosion.

3. University of Sydney Pattern Split Pole (Gillings) (Figure 10.9)
(The design is no longer in production but is still in use.) A magnetic unit 3.0mm in height, 5.5mm facio-lingually and 3.2mm mesio-distally. The design incorporates a stainless steel endplate and paired magnet configurations. It has negligible external field but only has approximately 300gms retentive force.

4. Jackson Rare Earth Attachment
Has 2 sizes, both of which incorporate a SmCo$_5$ magnet vertically enclosed in 2 stainless steel plates, which attract to a hemispherical stainless steel keeper.

The Regular Size (Figure 10.10) has a diameter of 4.8mm, the height of the magnet is 3.5mm and the height of the keeper is 1.2mm with a 0.5mm locating nipple which is centrally placed over the 8mm long, 1.5mm wide post.

The Jackson Mini (Figure 10.11) is of a similar configuration to the regular, that is, the magnet and endplates are arranged in the same way except the height of the magnet is only 2.4mm. The keeper is exactly the same except for the absence of the centralising nipple. The latest Jackson magnet is enclosed in titanium, weighs 0.56 grams and gives 560 grams retention (Table 1, page 129).

Figure 10.8: The Magnedent Attachment

Figure 10.9: The GMNlungs Split Pole Magnet
Figure 10.10: The Jackson Regular

Figure 10.11: The Jackson Mini
5. **The Gillings Mini Magnet (Keystone) (Figure 10.12)**
   
   Also a sandwich type magnet except the poles face horizontally. Flux is transferred through the endplates and completed by the keeper. This design provides similar retention to that of the split pole system using only half the magnet. The magnet is now produced as a hemisphere of 3mm height, 3.2mm wide and 3.6mm in depth. The magnet is machined to be totally enclosed and sealed within stainless endplates which prevent corrosion of the SmCo$_5$. Neodymium, Iron, Boron alloy magnets are also in the development stage, which provide greater retention.

6. **The Innovadent Neo Mini (Figure 10.13)** is a design similar in size and weight to the Mini except the magnet is perfectly sealed in a dome of stainless steel to prevent corrosion. It has a diameter of 4.35mm and retention of 475 grams (see Table 1, page 129).
Figure 10.12: The Gillings Mini

Figure 10.13: The Innovadent Neo Mini
A. Retention

The retentive properties of precision attachments depend upon:

1. Material of manufacture
2. Undercut retention
3. Frictional grip retention

The material with which the attachment is made determines its ability to elastically recover and thus provide resistance when one component is distorted against another. Consequently, the components are subject to wear and permanent distortion and depending on the type and quality of the materials used for the attachment, the durability of the attachment varies. Gold alloys, particularly of the Class III and IV alloys may be able to resist distortion and wear over thousands of insertions and removals. Other attachments, for example those using nylon or rubber 'O' rings, obviously wear much faster and need replacement much more frequently. However, all precision attachments relying on mechanical resistance to removal, do undergo wear and distortion.

Magnetic retention, on the other hand, does not suffer from this problem in that the magnetic attraction does not become less over a period of time under test conditions. However, it is true that magnets may lose retention in the mouth through another factor, which is the corrosive potential in the mouth environment. Unprotected SmCo$_5$ will corrode in the mouth, thus causing a gradual diminution of the magnetic flux both by increasing the air gap and by reduction in magnet size.
Thus retention depends largely on material of manufacture.

**Gold Alloys**

Due to the need for extreme hardness and toughness to resist the high loading and wear factors to which they are exposed, gold alloys are usually hardened by the addition of platinum and palladium. That is, they are usually of the type IV gold alloys used in denture base construction (Duckmanton and Taylor, 1975b). Precision attachment manufacturers use alloys of their own manufacture, which are patented and for which the exact proportions of the alloys are not provided. However, the characteristics of these different alloys are described and the specific functional characteristics of these alloys are employed for different components of the attachments.

As an example, Cendres and Métaux (1972a) use four basic types of gold alloys in their precision attachment selection.

**Metal 1 (O.S.V.)**

A very hard alloy of platinum, gold and palladium which is used as the non-flexing component of the precision attachment and is also the non replaceable component. This metal is designed to be the last component to wear.

Characteristics (Duckmanton and Taylor, 1975c):

Melting range

<table>
<thead>
<tr>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1870°F - 1960°F</td>
<td>or 1020°C - 1070°C</td>
</tr>
</tbody>
</table>

Brinell Hardness no.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>annealed</td>
<td>280</td>
</tr>
<tr>
<td>hardened</td>
<td>370</td>
</tr>
</tbody>
</table>

Ultimate Tensile Strength (lbs/sq" x 10^3)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>annealed</td>
<td>132</td>
</tr>
<tr>
<td>hardened</td>
<td>157</td>
</tr>
</tbody>
</table>

Yield Strength (lbs/sq" x 10^3)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>annealed</td>
<td>112</td>
</tr>
<tr>
<td>hardened</td>
<td>140</td>
</tr>
</tbody>
</table>

Percentage Elongation

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>annealed</td>
<td>18</td>
</tr>
<tr>
<td>hardened</td>
<td>12</td>
</tr>
</tbody>
</table>

This alloy is used for the following Cendres and Métaux components: the Conod Anchor patrix, the Dalla Bona cylindrical anchor and cylindrical resilience anchor matrices, the Battesti anchor split pin, the Gmür anchor friction sleeve and patrix, the BF cylindrical anchor patrix, the BF cylindrical stepped anchor matrix and patrix, the Rothermann eccentric patrices, the threaded bush and patrix components of the Gerber retention cylinder and retention buffer, the Schneider anchor threaded bush and patrix, the Schubiger screw block cap nut and soldering base, the Battesti anchor and resilient anchor split pins, the Biaggi resilient anchor threaded split ring and patrix, the CM round bar and the Hruska screw. In all cases except the Dalla Bona system, the hardest alloy is used in the component which is hardest to replace. This metal is generally supplied tempered and hardened if it is to be processed in acrylic, but when soldered, it must be hardened by heating to 400°C for 15 minutes, then quenching in water (Cendres and Métaux Catalogue, 1972b).

Metal 2 (Elitor)¹

A hard gold and platinum alloy usually used when hardness and durability is required but which will wear faster than metal number 1. It is usually used in components which are more easily replaceable. It has the following characteristics are (Duckmanton and Taylor, 1975c):

<table>
<thead>
<tr>
<th>Property</th>
<th>Annealed</th>
<th>Hardened</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting range</td>
<td>1650°F - 1795°F</td>
<td>900°C - 980°C</td>
</tr>
<tr>
<td>Brinell Hardness Number</td>
<td>155 (annealed) 280 (hardened)</td>
<td></td>
</tr>
<tr>
<td>UTS (lbs/sq&quot; x 10³)</td>
<td>94 (annealed) 118 (hardened)</td>
<td></td>
</tr>
<tr>
<td>YS (lbs/sq&quot; x 10³)</td>
<td>70 (annealed) 110 (hardened)</td>
<td></td>
</tr>
<tr>
<td>% Elongation</td>
<td>24 (annealed) 9 (hardened)</td>
<td></td>
</tr>
</tbody>
</table>

Components made from this metal include the Dalla Bona

¹. Cendres and Métaux, Biel-Bienne, Switz.
cylindrical and resilient anchor matrix and the Bona Ball-Anchor matrix and matrix, the Gmür anchor housing, the BF cylindrical anchor housing, the Gerber retention cylinder and retention buffer housings, the Schneider anchor housing, the Biaggi resilient anchor housing, the Dolder bar and housing, the CM rider, the Ipsoclip matrix and the Hruska matrix. Elitor is said to be self hardening but if soldered, it needs hardening by heating to 700°C for 30 minutes (Cendres and Métaux, 1972b).

Metal 3 (Elasticor)

The metal type used when good resilience and percentage elongation are needed. The metal is used commonly for clasp wire or for orthodontic finger springs and labial arch wires. It is only used in one attachment, the Rothermann cylindrical anchor matrix. It is a wrought alloy which is then tempered, rendering it more resilient on heat treatment. The matrix can either be processed in resin or soldered to the removable section of the appliance. The unit should be heat treated at 400°C for 15 minutes after soldering. The properties of this metal are (Duckmanton and Taylor, 1975c):

- **Melting range**: 1725°F - 1885°F
  - or 940°C - 1030°C
- **Brinell Hardness no.**: 151 (annealed) 230 (hardened)
- **UTS (lbs/sq" x 10^3)**: 98 (annealed) 128 (hardened)
- **YS (lbs/sq" x 10^3)**: 73 (annealed) 110 (hardened)
- **% Elongation**: 29 (annealed) 14 (hardened)

Metal 4 (Ceramicor)

This metal is used wherever an attachment is used in conjunction with porcelain fused to metal restorations. The metal is a high fusing alloy with a high platinum content. It is usually a little less hard,
has slightly lower yield strength and ultimate tensile strengths and a higher percentage elongation than the Type 1 metals. Ceramicor is non-oxidising and thus can be cast on to if the mould is preheated to 732°C. This type of gold can, in most situations, replace the normal gold/platinum alloys and is used in the Gmür anchor housing, in the Gerber anchor housing, and the Schneider housing, as an alternative to Elitor. It is used alone for the Conod anchor housing, the Battesti anchor and resilience anchor patrrix, retaining pins and matrix shells and the matrix sleeve of the Schubiger screw block, thus indicating the more common mode of use for these attachments.

Characteristics of Ceramicor are (Duckmanton and Taylor, 1975c):

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting range</td>
<td>2480°F - 2695°F or 1360°C - 1480°C</td>
</tr>
<tr>
<td>Brinell Hardness no.</td>
<td>160 (annealed) 240 (hardened)</td>
</tr>
<tr>
<td>UTS (lbs/sq&quot; x 10^3)</td>
<td>78 (annealed) 107 (hardened)</td>
</tr>
<tr>
<td>YS (lbs/sq&quot; x 10^3)</td>
<td>52 (annealed) 85 (hardened)</td>
</tr>
<tr>
<td>% Elongation</td>
<td>18 (annealed) 17 (hardened)</td>
</tr>
</tbody>
</table>

Ceramicor is heat treated by heating to 700°C for 30 minutes on a carbon crucible in a furnace, followed by hardening in a salt bath where it is soldered to a gold platinum alloy (Cendres and Métaux, 1972b).

Other precision attachment manufacturers do not necessarily follow such well ordered concepts on wear characteristics of the elements in precision attachments. Ceka attachments\(^1\) suggest attachments made from consistent materials throughout.

Type 1 metal (Au, Ag, Pd) is named "Fallax 1", which has a melting range from 1875°F - 1920°F or 1025°C - 1050°C

Brinell Hardness no. 204 (hardened)
UTS (lbs/sq" x 10^3) 85 (hardened)
YS (lbs/sq" x 10^3) N.A.
% Elongation 9 (hardened)

This metal is described as white gold and is used when soldering onto a post coping. It is heat treated by heating for 15 minutes at 400°C (Duckmanton and Taylor, 1975c).

Type 2 metal (AuPt) is named 'Orax 1" which has a melting range from

1690°F - 1725°F
or
920°C - 940°C

Brinell hardness no. 218 (hardened)
UTS (lbs/sq" x 10^3) 86 (hardened)
% Elongation 15 (hardened)

and is also described as being suited to direct soldering onto a post coping of yellow gold. Also it can be hardened by 15 minutes at 400°C (Duckmanton and Taylor, 1975c).

Type 4 metal (a Cobalt cast alloy) named 'Ceremax 1" is a high fusing alloy with

Melting range 2350°F - 2375°C
or 1275°C - 1300°C

Brinell Hardness no. 260 (hardened)
UTS (lbs/sq" x 10^3) 83 (hardened)
% Elongation 20 (hardened)

This alloy is designed for the direct casting technique and it fuses with all precious metals, but particularly porcelain/gold constructions. Heat treatment is done by heating to 700°C for 30 minutes on a carbon block in a furnace as with Ceramicor (Duckmanton and Taylor, 1975c).
The reason why Ceka components have consistent materials throughout may be to allow even wear between the components and the fact that both the matrix and matrix of the Ceka system are reasonably replaceable, if the standard coping design is used. In a situation where a component is not as easily retrievable, such as if the matrix were incorporated in a bar, it would be advisable to use the hardest of the three metals.

Other Materials Used in Precision Attachments

**Stainless Steel** - in some precision attachments 18-8 stainless steel split rings and springs are used as replaceable components where resilience cannot be achieved by gold components. Of note, the Gerber retention cylinder and retention buffer use stainless steel split rings and the Gerber buffer and the Ipsoclip use stainless steel replaceable coil springs. As stainless steel loses its resistance to corrosion if heated above 400°-900°C, these springs are designed to be assembled after final soldering and heat treatment.

The characteristics of stainless steel are:¹⁸⁹

<table>
<thead>
<tr>
<th>Property</th>
<th>Range</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brinell Hardness no.</td>
<td>190 - 330</td>
<td>(cold rolled)</td>
</tr>
<tr>
<td>UTS (lbs/sq&quot; x 10³)</td>
<td>70 - 125</td>
<td>(cold rolled)</td>
</tr>
<tr>
<td>YS (lbs/sq&quot; x 10³)</td>
<td>50 - 150</td>
<td>(cold rolled)</td>
</tr>
<tr>
<td>% Elongation</td>
<td>50 - 100</td>
<td>(cold rolled)</td>
</tr>
</tbody>
</table>

Obviously stainless steel components provide much better percentage elongation, however, they do eventually fail in function, probably as a result of corrosion and fatigue, and it is recommended to replace them, on a twelve monthly basis.
PVC Rings used in the Dalla Bona and Baer and Fah\textsuperscript{1} attachments and the Ancrofix attachment\textsuperscript{2} to provide the spacer for the retention leaves of the matrix to flex outwards. This ring is only essential during processing and is not necessary for function of the attachment.

Silicone Rubber Rings. Rubber rings, used as a method of retention in the custom made Quinlivan system (1974b), are suggested to be replaced regularly, due to the gradual deformation and wear of the 'O' rings and degradation of the rubber by infiltration into the silicone by yeast organisms. As the silicone hardens the resilience would decrease and retention would fall dramatically.

Nylon. The nylon patrices of the Zest system\textsuperscript{3} are subject to rapid wear due to deformation and abrasion of the plastic against the metal matrix. Abrasive particles inside the matrix also rapidly shorten the patrice's retentive life. Thus the Zest attachment is only recommended as an interim restoration according to Duckmanton and Taylor (1975a).

11.2 Retention Mechanisms

11.2.1 Undercut Retention

This involves a measured degree of flexion being required to be overcome before separation of the attachment is possible (see Figure 11.1). Many attachments involve some form of spring clip action, as this gives a more positive and recognisable seating of the appliance. Attachments using undercut retention include the Rothermann attachment, which uses a split ring, the B & F cylindrical stepped anchor and the Gerber attachment.\textsuperscript{1}

3. APM Sterngold, San Mateo, Calif., U.S.A.
Figure 11.1:

Diagrammatic representation of undercut retention for a precision attachment where the retentive arm length is determined by locating points A, B, and C, R = the radius of curvature, $\theta$ = the total included angle of the arm. Retention according to Frank and Nichols (1981) can be given according to the formula:

\[
\text{LOAD} = \frac{4 \ DEI}{R^2 \ (2\theta - \sin 2\theta)}
\]

where
- D = displacement
- E = Young's modulus
- I = moment of inertia of arm cross section.
As seen in Figures 11.2 and 11.3, the arrangement of a split ring system functions like two circumferential clasps acting together. The area of greatest undercut is indicated on the patrix by an inscribed line and this undercut fades to no undercut at all on the opposite side. This concept assumes that when the split ring is seated into position, the arms are only passively contacting the sides of the patrix. Consequently, in the resilient type of attachment (Rothermann 747 and the Gerber buffer) there would appear to be freedom for the prosthesis to move up and down over the height of the depressed section (normally 0.5mm).

Lamellae retention can also be combined with undercut retention, as in the Ancrofix, the Ceka, and the Schneider (page 84), whilst the Dalla Bona ball anchor and the Biaggi anchor use a combination of undercut retention and frictional retention. Of the bar units, the Ackerman bar, the CM rider, the Hader bar, the Baker clip and the oviform Dolder bar all use undercut retention of a lamellar form using anything from 2 leaves, as in the CM rider to 6 retention leaves as in the Schneider anchor.

Other forms of undercut retention methods include the B & C anchor, which is retained by two parallel wires running across a space inside a denture and which clip over an undercut gold stud patrix.

The Pressomatic and the Ipsoclip provide undercut retention through a spring loaded stud which is adjustable with a screw and which clips into a recess on the perpendicular opposing surface. "0" ring

4. Degussa.
Figure 11.2: The Double Clasp Arms of the Rothermann Attachment

Figure 11.3: The Rothermann Undercut
retention, as in the Quinlivan attachment, provides an undercut similar to lamellae retention in that deformation of the rubber around the whole circumference allows the patrix to snap into position.

11.2.2 Friction Grip Retention

This form of retention is provided by the resistance of sprung lamellae surfaces against parallel opposing surfaces (see Figure 11.4). For example, most cylindrical anchors provide this form of retention. These include the Dalla Bona cylindrical anchor, the Conod anchor, the Battesti anchor, the Introfix, the Gmür anchor, and the B & F cylindrical anchor. The Biaggi and Dalla Bona Ball anchor provide a combination friction/snap grip and the Dolder U bar and other parallel sided bars are all friction grip. As all purely friction grip anchors have no defined "snap", they are all capable of a degree of vertical resilience, whilst maintaining retention. However, rotation around the attachment is not possible.

The Dalla Bona cylindrical anchor provides "soft" retention by the light lamellae configuration. The Conod, Biaggi and Battesti attachments feature a split pin or split ball arrangement (in effect two lamellae) and in the case of the Biaggi, this also opposes a split ring, which allows 2 areas of adjustment in this attachment.

11.3 Retention Adjustment

With wear and metal fatigue, the retention force decreases markedly and is compensated for by adjustment to the retentive lamellae, either to reposition the lamellae back into the undercut or to increase

Figure 11.4:
Retention in a frictional attachment is achieved by increasing the surface area of contact at the expense of deflection. Retentive load remains a function of

\[ \text{LOAD} = \text{D.E.I.S.} + \text{F} \]

where
- \( D \) = displacement
- \( E \) = Young's modulus
- \( I \) = the moment of inertia of the arm in cross section
- \( S \) = the total surface area in contact
- \( F \) = frictional resistance due to surface roughness
the deflection of the lamellae when engaged on a parallel surface.

Tools are provided in the case of split pin or split ball attachments, e.g. the Battesti retention adjustor\(^1\) (Figure 11.5). Simple leverage force applied by a fine screwdriver to the lamellae is required in most cases to adjust the retention, or it may need complete replacement of the retentive components in the case of non-adjustable attachments.

11.4 Retention Studies

Retention studies for precision attachments are few. One study done under the guidance of Gillings (1987) suggested retention figures on a selection of attachments.

The Ceka anchor\(^2\) giving 1,000 grams retention
The Dalla Bona 604\(^3\) attachment 400 grams retention
The Kurer Anchor\(^3\) 300 grams retention
And his University pattern magnet 300 grams retention

A comprehensive study by Stewart and Edwards in 1983, compared retention figures of five precision attachments before and after wear cycles up to 44,000 times. They considered stages of wear at 1 year (1100 cycles), 2 years (2200 cycles), 6 years (6600 cycles), 10 years (11000 cycles), 20 years (22000 cycles) and 40 years (44000 cycles) on the Kurer press attachment,\(^3\) the Ceka 691 attachment,\(^1\) the Gerber cylinder\(^1\) (resilient), the Dalla Bona cylinder attachment\(^1\) and the Rothermann eccentric attachment\(^1\) (non resilient). The Kurer anchor gave the highest retention figures - 1.9 kgs initially, 2.6 kgs at 2,200

Figure 11.5: The CM Retention Adjustor
cycles, then back to 1.4 kgs at 44,000 cycles. The authors believed this initial increase in retention to be due to surface roughness. The Rothermann started at 0.4 kgs and dropped to 0.2 kgs at 44,000 cycles. The Gerber started at 1.2 kgs and dropped to 0.37 kgs but returned to 0.78 kgs when a new slit steel ring was placed. The Dalla Bona dropped from 0.95 kgs to 0.33 kgs and the Ceka displayed least wear, only dropping from 0.84 kgs to 0.74 kgs in 44,000 cycles.

Other figures by Jackson in 1986 detail initial retention figures of

The Gerber buffer$^1$ 1200 grams
The Dalla Bona cylindrical anchor$^1$ 1000 grams
The Ceka attachment$^2$ 850 grams
The Zest Attachment$^3$ 750 grams
The Rothermann attachment$^1$ 425 grams

Also, an "O" ring attachment, the O-SO attachment$^4$ (similar to the Quinlivan attachment, was determined to be 775 grams.

All these attachments are being compared to magnetic attachments on the basis of retentive force reduction in relation to breakaway cycles. It can be noted that all metal attachments lose retention as a direct function to number of breakaway cycles. Jackson notes the Gerber drops from 1200 grams to 600 grams retention after 25,000 cycles. The Dalla Bona cylindrical anchor drops from 1,000 grams to 550 grams after 25,000 cycles, the Ceka from 850 grams to 650 grams after 25,000 cycles

3. APF Sterngold, San Mateo, Calif.
4. Scodenco, Tulsa, Oklahoma, U.S.A.
and the Rothermann falls from 425 grams to just under 200 grams after 25,000 cycles.

The non metallic attachments demonstrate a more rapid fall off in retention. The Zest falls rapidly from 750 grams retention to 250 grams retention after only 5,000 cycles and fades away to no retention after 18,000 cycles. The O-SO attachment does a little better, fading from 775 grams retention to 250 grams after 10,000 cycles, although it too loses all retention by 22,500 cycles. Another factor to consider is the fact that metal attachments are generally adjustable to improve their retention, whilst the non metallic attachments need full replacement.

Magnetic attachments, according to this study, give a constant retention value which is not affected by breakaway cycles. The Jackson regular attachment maintains 720 grams, the Jackson mini maintains 575 grams, the latest Innovadent magnet gives 600 grams (Gillings, 1987), the Gillings split pole gives 300 grams, the Magnedent gives 240 grams and the Dyna Magnet gives 200 grams retention.

However, there is another factor, not mentioned by Jackson (1986), which affects magnetic retention in the mouth. Cobalt samarium magnets, which are exposed to occlusal forces and oral fluids, will rapidly corrode, resulting in dramatically cut retentive forces, according to Gillings (1987). Complete sealing of the magnet in a stainless steel housing, as in the Innovadent magnet, appears to give better long term results. However, as has been noted clinically by Gillings (1987), unprotected magnets retained against soft iron keepers have been in function for over 10 years, in some cases without appreciable loss of retention, indicating that corrosion may not be the complete cause of loss of retention in current magnets.

1. Innovadent, Pymble, N.S.W.
Also, in the case of magnets, it can be true to say that within a certain design concept, the size of the magnet has a lot to do with retention. The larger the magnet, the more the retention, but with a consequent loss of convenience in fitting the magnet within the denture base. As shown by the latest retention readings by Gillings (1987) of all the currently available magnetic attachments, the size of the magnet makes a significant difference to the amount of retention available. The important factor in magnetic retention is the ratio of retention grams to grams of attachment. The smaller the retention unit the more convenient its use; therefore a small unit with good retention is the optimum (see Table 1).

One reason for the effectiveness of the Innovadent mini retention units is the use of Nd$_2$Fe$_{14}$B magnets which give a 13% increase in retention. Also increased in these magnets is the remanence (to 11,500), intrinsic coercivity (resistance to demagnetisation) (to 19,000) and magnet field strength (from $19 \times 10^6$ to $31 \times 10^6$) (see Table 2).

11.5 Factors Involved in the Alteration of the Retentive Parameters of Precision Attachments

Retention in precision attachments is related to the amount of force required to overcome a function of the elasticity of the material, the amount of the deflection, the moment of inertia, the surface roughness and the surface area (Figures 11.1 and 11.4). The reason the Dalla Bona ball gives 400 grams initial retention and the Dalla Bona cylinder gives 1,000 grams retention can most easily be explained by an increase in the surface area of a cylindrical type of attachment.

However, in reality in the mouth retention of the prosthesis may
TABLE 1

| Magnet attachment                          | Weight (gms) | Retention (gms) | Ratio  
|-------------------------------------------|--------------|-----------------|--------
| Innovadent Mini NdFeB Retention Units     | 0.22         | 510             | 2318/gm
| Magnadent (small)                         | 0.22         | 215             | 935/gm
| Innovadent Neo Mini NdFeB Retention units | 0.23         | 475             | 2065/gm
| Dyna attachment                           | 0.32         | 135             | 422/gm
| Shiner Stress Directing Magnet (magnet only) | 0.35         | 720             | 2057/gm
| Jackson large                             | 0.39         | 780             | 2000/gm
| New pattern Jackson large                 | 0.56         | 560             | 1000/gm
| Magnadent large                           | 0.43         | 310             | 721/gm
| Innovadent Maxi CoSm Retention Units      | 0.56         | 980             | 1750/gm
| Saco magnet (no longer in production)     | 0.64         | 90              | 140/gm 
TABLE 2

<table>
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<th></th>
<th>Co$_5$Sm</th>
<th>Nd$<em>2$Fe$</em>{14}$B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remanence, B (residual induction) Gauss</td>
<td>8,900</td>
<td>11,500</td>
</tr>
<tr>
<td>Intrinsic Coercivity, $H_C$ (resistance to demagnetisation) Oersted</td>
<td>17,000</td>
<td>19,000</td>
</tr>
<tr>
<td>Max. Energy Product $BH_{max}$ (magnet field strength) Gauss Oersted</td>
<td>$19 \times 10^6$</td>
<td>$31 \times 10^6$</td>
</tr>
</tbody>
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demonstrate considerably more force than would be expected from these results. Other factors obviously have an effect on these retentive values. Factors relating to the individual attachment design, technical procedures, and case design all may have a perceivable effect on attachment retention values.

To date no research has been embarked upon to examine these factors. The research component of this thesis was designed to examine one of these factors: the effect on precision attachment prostheses' retention by varying the path of withdrawal (see page 188).

As can be demonstrated, changes in the path of withdrawal drastically alter the retention values of the attachments leading one to consider the consequences to the abutment teeth.

Other factors affecting retention include:

a) The freedom of the attachment to function.
Any attachment which functions by deflection must be allowed to function. Any material which prevents the functioning of the retentive arms of an attachment will increase the retention. Acrylic or any hard material not cleared from behind the retentive arms may either dramatically increase the retention or prevent the attachment to function. If any material prevents a magnetic attachment sitting perfectly on the root face the magnetic retention will be decreased.

b) Incorrect alignment of the processed attachments through incorrect or excessive path or insertion discrepancy.
In most precision attachments, if more than one attachment is used, milling of the abutment face is necessary and soldering of the attachment must be done in the correct path of insertion. The longer the attachment and more cylindrical an attachment is,
the more critical the parallelism of the attachments becomes. The Rothermann, some ball attachments and the Zest allow some divergence in the path of insertion - but it causes more rapid wear and force on the abutment.

c) Incorrect alignment of the matrices to the patrices. During acrylic processing, incorrect alignment can occur which can cause a change in retention. This type of problem can occur particularly when components are processed with insufficient relief being provided around a matrix (Figure 11.6). Malalignment causes stress on the abutments, eccentric wear patterns and more rapid loss of retention in the attachments.

d) Overadjustment of Attachments.
Manufacturers suggest that the attachments should be initially adjusted for minimal retention, then the retention gradually increased to suit the patients' needs. Overadjustment causes excess flexing of the attachment past the distortional limit of the retentive arms or lamellae. Fatigue of the metal leads to eventual breakage.

As noted by Stewart and Edwards (1983), retentive forces in the order of 1.0-2.0 kgs would not cause damage to a healthy periodontium if you only take extractive forces into account. From my study, retention may have a role in tissue damage of another nature. Caldwell (1962) showed that sticky food can exert 1.5-2.0 kgs lifting force on a free end saddle. This force is not necessarily applied directly vertically to an attachment, therefore force, up to the breakaway load, can be applied either to the abutment root, in the case of a cylindrical attachment, or to the anterior tissues. If, in the case of two lower canines,
Figure 11.6: Illustrating the consequence of improper alignment of attachment matrixes during technical phases. Distortion of the attachment and/or damage to the abutment can result.
prominently positioned in the anterior ridge, the Dalla Bona Ball attachment, the Rothermann or Kurer studs would allow rotation of the denture base and pressure against the labial root eminences with a leverage factor magnifying these forces.

Periodontal consequences of this force may explain the rapid recession that can occur in this region.

On the other hand, as explained by Stewart and Edwards (1983), the design of the attachment and its ability to transmit less force to the abutment, may be the key to maintenance of the abutments, particularly in the lower jaw where ridge shape provides less of an aid to support for the prosthesis.
CHAPTER 12

ATTACHMENT DESIGN RELATED TO THE STRESS
ON TEETH AND TISSUES ON LOADING

12.1 The Effect of Resilient and Rotatory Designs under Vertical Loading

Resilience indicates that provision has been made in the attachment for movement vertically under functional loads. In theory, resilient attachments allow the denture to be supported by the tissues and the abutments equally. Resilient anchors are used, usually for complete dentures, where there are insufficient abutments to allow complete tooth support for the denture. Vertical translation of 0.4mm is provided in most resilient attachments except for the Rothermann, which provides 0.6mm and the Dalla Bona Buffer (no. 604P) which provides 0.8mm. The Gerber buffer and Dalla Bona buffer attachments both provide steel return springs which are said to allow functional loading of the abutments under light loading. Compensation for the resilience of the tissues and the attachments must also be made over the root face and aluminium spacing rings are provided to adapt to the root face during processing (a double spacer is used when processing the Bona buffer). Preiskel (1968) notes that it is essential, in any overdenture case, for the lateral stabilisation provided by the denture base to be equally important in preservation of the remaining abutments.

Non resilient attachments, which are primarily used for removable bridges and partial overlay dentures or bar splinting designs, can be used in full overlay denture cases, as long as there are a sufficient number of teeth of sufficient strength to support the denture alone, i.e. a "tooth supported" prosthesis. Most attachments
can become non resilient if the denture needs relining and the load is being taken mainly by the teeth due to lack of tissue support, or if the spacer has been omitted during processing.

Resilience is a concept of design which compensates for the effects of vertical loading. As tissues are comparatively more compressive than teeth (0.5mm compared to 0.1mm), the abutment teeth would indeed sustain most of the load when the denture base is loaded. In a free end saddle situation, rotation also tends to occur, causing loading at the distal ends of the saddles. In the case of a cylindrical attachment adjacent to a free end saddle, the torquing force must be taken by the root abutment if the abutment does not allow vertical movement until it is tissue supported. Consequently, resilient attachments normally allow 0.4mm vertical movement by an addition of spacers of this diameter on processing. This technique assumes that the prosthesis is accurately fitting and the relationship of the denture base to the abutments is maintained by relining. Potential rotation of the abutment (Figure 12.1) results when the prosthesis becomes tooth supported. Rotatory precision attachments make allowance for the fact that the ideal cannot always be maintained and that the denture base will rotate and thus torque the abutment on mastication. However, forces generated by entirely rotational allowance are not necessarily favourable (Figures 12.2 and 12.3).

Thayer and Caputo (1980) discuss the selection of precision attachments on the basis of force transmission and the suitability of the abutments. Due to the fact that chewing forces increase when attachments are placed, particularly in the mandibular overlay denture, according to Sposetti et al. (1986), the effect of the attachment design on the abutment is particularly relevant. In their studies, Warren and
Figure 12.1 (above and below):
The Theoretical Concept of Resilient design
Figure 12.2: The Effect on the Abutment and Tissues of a Purely Rotational Attachment under Load.

Figure 12.3: Resilient Design Allows more Even Distribution of Forces.
Caputo (1975) and Thayer and Caputo (1977, 1979) examined load transmission on conventional non-attachment designs including the amalgam plug, dome coping and coping with an occlusal concavity, extracoronal stud attachments including the Ceka,1 Bischof-Dosenbach attachment,2 the Rothermann attachment,3 the Gerber attachment,3 and the Ancrofix attachment,4 an intracoronal attachment, the Zest Anchor,5 and three types of bar attachments, the Dolder bar,3 the King connector6 and the Hader bar.5

Analysis was carried out by comparison of the photoelastic stress patterns produced by loading the denture base in certain directions.

When applying vertical forces, they found that stud attachments exerted forces to the abutments according to design. The Ancrofix, which is a resilient attachment allowing vertical and rotatory movement, causes less torquing force to be exerted on the abutment on vertical load compared to the Ceka and Bischof-Dosenbach attachments and to some extent for the Rothermann and Gerber attachments. In other words, the more rigid the attachment, the more force it will exert. This is also true for the Zest attachment, which showed more torquing than the Ancrofix, probably as it is quite tightly fitting in the matrix when the matrix is new.

Bar restorations appear to be advantageous due to their splinting effect, but only if they are of a resilient design. A resilient Dolder

2. Bischof-Dosenbach Co., St. Louis, Mo.
3. Cendres and Métaux, Biel-Bienne, Switz.
5. APM Sterngold, San Mateo, Calif.
6. Ultratek Attachments and Technology, Concord, Calif.
bar produced less torquing on the teeth than Zest anchors on vertical loading. The same does not apply to non resilient designs such as the King Connector and to a lesser degree the Hader bar, which only allow rotatory movement.

Another study by Igarashi in 1975, gives more quantitative figures on the effects of attachment design on tooth mobility under load. Instead of stress patterns, actual measurements of tooth movement under load were carried out on simulated cases. Forces were compared to the movement caused when a simple clasped tooth was loaded and when other root cap designs were loaded in the same manner. Mobility changes depended on where the vertical load was applied. The Dalla Bona 604\(^1\) (comparable to the Ancrofix) reduced the mobility to 36% if loaded in the anterior region and 54% if loaded posteriorly on the denture base.

The Conod anchor\(^1\) reduced mobility to 41% loaded anteriorly, but increased mobility to 203% when loaded posteriorly. Bar attachments with rotatory function actually decreased the mobility when loaded posteriorly to 34% compared to anterior loading (41%) and gave the lowest figure overall for the posterior vertical loading.

Vertical loading in magnetically retained overlay dentures have been discussed by Jackson (1986) who empirically decided that a rounded dome shape of the keeper was preferable to allow maintenance of the magnet contact during vertical loading. However, as distinct from a resilient design, magnetic attachments are tooth supported dentures and thus rotatory designs may allow tissue pressure around the abutments. The exception to this may be the Shiner attachment which allows more resilience via the magnet housing; however, this has not been tested. As mentioned by Jackson (1986), flat faced magnets may "pop" in function

and allow escape of the magnetic field, however, as discussed by Gillings (1987), this may not occur as the magnetic flux will bridge the gap when it does occur and the field strength of the magnet drops as an inverse cube to distance. In effect, a flat root face encourages recovery of the denture position in the mouth (Figures 12.4 and 12.5).

12.2 **Horizontal Loading**

The effect of horizontal loading on abutments is a major consideration in the analysis of force distribution. There are two schools of thought as to the type of loading which is more advantageous to the root. Horizontal loading could be transmitted to the abutments by occlusal forces operating in lateral movements and may be the cause of mobility changes in the abutments. Lateral stability in prostheses varies from patient to patient, depending upon the individual anatomy, e.g. differences in the residual ridge height and the depth of the muscular attachments. It is mandatory that full advantage should be taken of the oral structures in the design of the denture base. However, horizontal loading effects must play a role in the health of the abutments.

Fenner, Gerber and Mühlemann's study (1956) discussed tooth mobility changes in abutment teeth, which take place after partial denture placement. Generally, they showed that mobility increased after placement of partial dentures. This study is backed by other studies, e.g. Igarashi (1975) which use the unrestored tooth in a partial denture as the baseline in mobility studies. Gerber's work (1964), showing the effect of loading the denture base simulating shearing forces, illustrates the tipping forces that can occur on abutments under horizontal loading (Figures 12.6 and 12.7). This model illustrates that
Figure 12.4: Schematic Diagram of Magnetic Attachment Adjacent to a Free End Saddle Under Load.

Figure 12.5: Tissue Contact Under a Magnetically Retained Overlay Denture
Figure 12.6: The Effect of Horizontal Loading on Abutment with Cylindrical Attachment.

Figure 12.7: The Effect of Horizontal Loading on Abutment with Ball Attachment.
horizontal forces alone or in combination with occlusal forces, cause tipping in ball type attachments. Fenner et al. (1956) described the tipping force allowed by a rigid attachment to be only one quarter that allowed by free movement, when horizontal forces are applied (Figure 12.8) (Mensor, 1975).

However, this simplistic model may be more complex in the clinical situation. Mobility initially would certainly be less due to the buttressing effect provided by a solid wall of bone. Orthodontic procedures have shown that bodily movement of teeth requires much more force than that force which is required to tip a tooth. A force of 3 kgs applied over a period will certainly result in movement, even when it is a rigid attachment.

From the studies done by Warren and Caputo (1975) and Thayer and Caputo (1977, 1979) and by Igarashi (1975), the more rigid the attachment, the more the force is transmitted to the abutment under all directions of force. It could be argued that rather than causing tipping, a rotationally resilient attachment would allow the denture base to take more of the load and thus prevent overloading of the abutment. Splinting of two abutments, as has been found by Thayer and Caputo (1977), with a resilient, rotational unit, such as the Dolder bar,\(^1\) enhances this effect by doubling the surface area of the root at the same time as transferring a large amount of the load to the tissues. Dolder (1961) has described the splinting effect which unites the abutments to form basically a two rooted tooth. Ideally, for the best mechanical advantage, the bar should be positioned perpendicularly to the line bisecting the angle between the posterior ridges (Figure 12.9). Dolder suggests that lateral translatory movements are impossible with a

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\(^{1}\) Cendres and Métaux, Biel-Bienne, Switz.
Figure 12.8: Mobility Measured in Hundredths of a Millimetre of a Tooth Restored with a Rigid Attachment (II) Compared to a Ball Attachment (I) when Loaded Horizontally.
Figure 12.9: The Ideal Position for Bar Placement According to Prieskel (1967). The bar is positioned perpendicular to the line bisecting the angle between the posterior ridges.
bar sleeve attachment, which he believes protects the alveolar ridges from atrophy. Of course these forces are still present during mastication and must therefore be borne by the abutments.

Preiskel (1967) notes that the Dolder bar is best used for patients with square arches and where remaining roots can be joined in a straight line. Without the ability for rotational function, the bar is more rigid in nature, thus developing more stress to the abutments even in vertical loading. As the abutments are splinted together, a weak abutment, rather than being an aid, may be detrimental to a healthy abutment. If one abutment becomes mobile for any reason, whether it be pulpal, periodontal or functional, the bar may become just a long cantilever arm, with severe rotational and tipping forces possible. For this reason alone, a system such as the Schubiger screw block is an advisable addition to allow conversion of the case to a simple stud. Jumber (1981a) suggests that if abutments are strong enough, stabilisation in more than one plane can be achieved by cantilevering one or two short bars distal to the abutments. Igarashi (1975) shows that the effect of distal extensions to the bar significantly increases the abutment movement when force is applied posteriorly both from the occlusal and the lateral directions.

Occasionally it may occur, that there remain abutments on one side of the arch, in which case Dolder (1961) describes the bar joint as valuable. The three degrees of freedom of movement of the bar joint remain principally the same, however, loading may be unequal and therefore the resilient component of the bar joint must function to allow bilateral and even occlusal contact.

Stress analysis done on other types of bar systems by Thayer and

Caputo (1979) demonstrated that a rigid bar system showed much greater torquing force on the abutments. All bar designs appear to exert more stress on the contralateral side, than did the stud or conventional designs. This may be explained by the greater area of surface contact between the bar and the denture via the sleeve, and by the splinting effect of the bar. According to Dolder (1961), this effect may be limited by the fact that a sleeve arrangement allows a lever effect along the long axis of the bar when the denture is depressed from one side only.

Magnetic attachments apply the least lateral forces to abutments of all precision attachments, due to the ability of the flat face of a root cap to allow slip and still maintain the same retention. This lateral freedom is theoretically achievable in all magnet systems with flat faces. The Jackson magnets are, however, contoured to allow rotational movement and on the Jackson regular, there is a central pin which prevents lateral movement. Consequently, lateral stress must be greater on these types of attachments causing the tipping forces described by Gerber (1964). Ideally, lateral freedom is best achieved by "cement in" keepers, which produce a flat surface next to the gingival margin. "Cement on" keepers however, are much more clinically practical in many cases so true lateral freedom may not be as predictable. In any case, the contour of the periradicular structures, for example, the root and ridge contour, the attached gingiva and exposed root surface, must also contribute to the limitation of lateral movement. Excessive lateral movement is, of course, undesirable because of the effect on the occlusal scheme of the overdenture. More lateral stress may be produced if correct balance of the occlusion cannot be maintained because of the lateral movement in the denture base. In
effect, magnetic systems are "horizontally resilient", not vertically resilient, the position of the denture being determined more by tissue contour than by precision attachment position.

12.3 Indirect Retention

In every case involving free end saddle prostheses, the lifting force caused by the pull of sticky foods causes a rotation of the denture around the fulcrum of the two most distal retainers. As has been demonstrated by my experimental component, rotational attachments can exert pressure on labial tissues on removal, which may well be detrimental. Ideally, consideration of some form of indirect retention should be made in the design of the overlay denture. Resistance of the denture to rotation around the most distal abutments is ideally provided by an additional abutment anterior to the retaining abutments. Only precision attachments which allow rotational movement would require indirect retention. If no anterior abutments are available, the next available structure would provide the resistance - for example, any alveolar ridge anterior to the abutments. If no horizontal surface is available, the vertical surface of the denture base would then take the load.

Due to factors already discussed under retention, the tissues labial to the root may be the least desirable of all to be used as an indirect retainer. In a case such as this it may even be preferable to have no labial flange over an abutment, if no other area of indirect retention can be obtained. Table 3 details the effect of different loads on abutments restored with precision attachments as influenced by their position on the alveolar ridge. If we order the situations into which rotational retainers would be best applied with regard to indirect
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<th>CASE TYPE</th>
<th>ATTACHMENT TYPE</th>
<th>LOAD TYPE</th>
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</thead>
<tbody>
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<td></td>
<td>DIRECT</td>
</tr>
<tr>
<td>1. Anterior Abutment most labial</td>
<td>NO ATTACHMENTS</td>
<td>No torquing</td>
</tr>
<tr>
<td></td>
<td>CONOD</td>
<td>Heavy torquing</td>
</tr>
<tr>
<td></td>
<td>DALLA BONA BALL (resil)</td>
<td>Tissue bearing</td>
</tr>
<tr>
<td></td>
<td>GERBER</td>
<td>Some torquing</td>
</tr>
<tr>
<td></td>
<td>MAGNET</td>
<td>Tooth bearing axial loading</td>
</tr>
<tr>
<td>2. Abutments in Premolar Region</td>
<td>NO ATTACHMENTS</td>
<td>Heavy axial loading</td>
</tr>
<tr>
<td></td>
<td>CONOD</td>
<td>Heavy torquing</td>
</tr>
<tr>
<td></td>
<td>DALLA BONA BALL</td>
<td>No torquing</td>
</tr>
<tr>
<td></td>
<td>GERBER</td>
<td>Minimal torquing</td>
</tr>
<tr>
<td></td>
<td>MAGNET</td>
<td>Pivot point for denture</td>
</tr>
</tbody>
</table>
TABLE 3 (cont.)

<table>
<thead>
<tr>
<th>CASE TYPE</th>
<th>ATTACHMENT TYPE</th>
<th>LOAD TYPE</th>
<th>DIRECT</th>
<th>LATERAL</th>
<th>LIFTING</th>
</tr>
</thead>
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<tr>
<td>3. Abutment anterior to attachment abutment</td>
<td>NO ATTACHMENTS</td>
<td>Axial loading</td>
<td>Tipping or dislodgement</td>
<td>Dislodgement</td>
<td></td>
</tr>
<tr>
<td>CONOD</td>
<td>Heavy torquing</td>
<td>Some bodily movement</td>
<td>No torque (indirect retainer present)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DALLA BONA BALL (resil)</td>
<td>No torque (tissue sharing load)</td>
<td>Less tipping as load shared by extra abutment</td>
<td>No torque (indirect retainer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GERBER</td>
<td>Some torque</td>
<td>Minimal bodily/tipping movement</td>
<td>No torque</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAGNET</td>
<td>Pivot point axial loading</td>
<td>Minimal force</td>
<td>Axial lifting no greater than breakaway force</td>
<td></td>
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</tr>
</tbody>
</table>

<p>| 4. Adjacent abutment distal to attachment abutment | NO ATTACHMENTS | Axial loading no torquing | Minimal tipping | Dislodgement |
| CONOD | No torque | Slight bodily movement | Torquing of abutment |
| DALLA BONA BALL | No torque | Axial lift if distal abutment unrelieved | No torque | Pressure on labial tissues |
| GERBER | No torque | No torque | Labial pressure and torquing |
| MAGNET | Shared axial loading | Shared minimal loading | Minimal tissue loading less than eccentric breakaway force |</p>
<table>
<thead>
<tr>
<th>CASE TYPE</th>
<th>ATTACHMENT TYPE</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>DIRECT</td>
</tr>
<tr>
<td>5.</td>
<td>NO ATTACHMENTS</td>
<td>Axial load</td>
</tr>
<tr>
<td></td>
<td>CONOD</td>
<td>No torque</td>
</tr>
<tr>
<td></td>
<td>DALLA BONA BALL (resil)</td>
<td>No load if resilient Axial if non resilient</td>
</tr>
<tr>
<td></td>
<td>GERBER</td>
<td>No load if resilient Axial if non resilient</td>
</tr>
<tr>
<td></td>
<td>MAGNET</td>
<td>Axial loading (shared)</td>
</tr>
</tbody>
</table>
retention, we could deduce:

1. Distal abutments for Kennedy Class I partial dentures, where anterior teeth can be used for indirect retention, are more favourable than
2. Distal abutments with one or more anterior abutments as indirect retainers, are more favourable than
3. Anterior retainers but with alveolar ridge anterior to the attachments, are more favourable than
4. Anterior abutments prominently placed on the alveolar ridge.

Depending upon the shape of the root cap, the labial face could in fact be adjusted to resist lifting forces rather than being taken by the tissue, however, this was not considered in the manufacturer’s design. It may, in fact, torque the tooth more than is desirable.

Modifications in attachment design could be envisaged on the basis that rotation onto the labial face is undesirable but that rotation under occlusal load is desirable, for example, a Dolder bar with vertical surface anteriorly and a pear shape posteriorly or a Dalla Bona ball attachment which is cylindrical on the labial face and becomes a ball posteriorly.

Excellent gingival contour can be demonstrated clinically on root caps which are associated with partial dentures however, and disappointing gingival responses may not necessarily be entirely due to poor oral hygiene when these forces play a role.
CHAPTER 13

COPING DESIGNS FOR ATTACHMENT FIXATION

The requirements of a coping used to house a precision attachment are quite different to those without. Here the dome shape of the coping is not required to restore tooth contour and provide axial loading.

Coping design for precision attachments can be divided into two components.

13.1 The Internal Design
13.2 The External Design.

13.1 The Internal Design

From the studies done by Thayer and Caputo (1977, 1979, 1980), Thayer, Warren and Caputo (1975), Sposetti et al. (1986), Igarashi (1975) and by my own segment on retention figures, it is obvious that high forces can be applied to the abutment through the coping. The internal requirements of the coping to resist these forces are the following.

a. To resist dislodgement both vertically and rotationally.
b. To provide resistance form - to prevent root fracture.
c. To provide adequate bulk to facilitate soldering of the component parts.

The internal design for attachment copings comprises the following components (Figures 13.1, 13.2 and 13.3):

13.1.1 The post
13.1.2 The internal seat
13.1.3 The chamfered margin
13.1.4 Accessory Pins.
Figure 13.1: Root Face Preparations for Precision Attachment Copings
Precise Attachment Root Cap Preparation

1. Root face
2. Eccentric locating seat
3. Post preparation
4. Chamfer
5. Central hollowed out area to ensure adequate thickness for soldering.

Figure 13.2: Root Face Preparation

1. Central hollowed out area
2. Eccentric locating seat
3. Post preparation
4. 10° chamfer (1.00mm long)
5. Epithelial attachment line

Figure 13.3: Root Canal and Root Face Preparation in Cross Section
13.1.1 Posts

Various authors have described the function of a post. Standlee et al. (1978) describe the function as follows:

a) To protect the tooth weakened by endodontic therapy against concentrated internal stresses and root fracture.

b) To provide adequate retention for a restoration to function within various dentitions.

Whilst some authors, such as Greenwald (1965) and Johnson et al. (1976), concentrate on only the use of the dowel and core to replace lost tooth structure, other authors concentrate on the ability of post cores to protect the remaining tooth structure from fracture. Weine et al. (1973) suggest a post system which at no time during the canal preparation uses rotary instruments at either low or high speed which, they believe, risks fracturing, ledging or perforating the root. Standlee et al. (1972) and Henry (1977) stress the post core system which best protects the remaining tooth structure must be the one of choice. Kurer (1967) believes a post must firstly establish firm and permanent anchorage and secondly, it must support the restoration. The function of the post in root cap design becomes very important in the light of the stresses being placed on the abutment.

13.1.1.1 Post Retention and Resistance for the Attachment Coping

Regardless of the forces acting upon it, the dislodgement of a post results from a shearing strain to the post, cement and dentine interfaces.

Retention of the post depends mainly upon:

a) The post design
b) The post length
c) The post diameter
d) The type of cement used.
Other factors which may influence retention are:

e) The closeness of fit of the post to the internal surface
f) The presence of venting
g) The seating force used in cementation
h) The degree of surface roughness of the post and preparation
i) The post material.

a) The Post Design

According to studies done by Colley et al. (1968), Kurer et al. (1977), Standlee et al. (1978) and Johnson and Sakumura (1978), the post design is a critical factor in post retention (see Table 4 in Chapter 15, page 197). Although forces acting on a post may not be in an axial direction and shear forces require complex mathematical calculations such as those by Hedgord and Silness (1977), the experimental work on post retention has all been done by measurement of dislodgement forces in the path of insertion of the post. Colley et al. (1968) measured the retention of 3.5-8.0mm posts and found that two factors influenced retention most. Firstly, the presence of serrations allowed four times the retention in a 5mm parallel post and six times the retention in an 8mm post (60 kgs retention). Secondly, the degree of taper influenced retention: a 5.5mm serrated parallel post gives approximately 25 kgs retention compared to 17 kgs retention for a 3.5° convergence post and an 8.0mm serrated parallel post gives 57 kgs retention whilst a 3.5° serrated post gives only 29 kgs retention. The differences between smooth posts of all tapers is much less consistent. Overall, they found that parallel sided serrated posts provided the most retention.

Kurer in 1977 tested the retention of dowels in whalebone and agreed basically with Colley et al.'s results on tapered and grooved dowels. The retentive values of his screwed posts far exceeded the
values of the other posts ranging from the lowest values of a 4mm long, 1.82mm diameter post requiring 56.5 kgs force to remove it, up to a 10mm long, 1.58mm post requiring 140.5 kgs force to remove it. Naturally, as this technique does not rely on cement for retention, the retention values must reflect the hardness of the tooth structure, and its surface area, which must be broken through to dislodge the post.

Standlee and Caputo tested tapered, parallel and screwed posts for retention values in 1972 using standardised posts of 8mm and 5mm. They found that the tapered Unitek\textsuperscript{1} which matches endodontic files with a 0.54 degree taper, provides retention between 9 kgs for a 5mm post of 1.78mm diameter, to 13.5 kgs for an 8mm post of 1.78mm diameter. A Whaledent Parapost\textsuperscript{2} 1.78mm diameter of 5mm length, gives 25 kgs retention and an 8mm post gives 45 kgs retention. The Kurer post\textsuperscript{3} at 1.78mm was found to give 78 kgs retention at 5mm length and 88 kgs retention at 8mm length.

Johnson and Sakumura in 1978 found the major contributing factor to an increase in retention was the shape of the dowel, which was determined when comparing the Whaledent Parapost\textsuperscript{2} and Endo-Post tapered dowels.\textsuperscript{4} Tests done using a slowly removing tensometer,\textsuperscript{5} which measured retention before and after initial breakage of the cement bond, clearly showed that parallel sided dowels resist tensile forces 4.5 times greater than tapered dowels. Also, it was shown that parallel sided dowels could not be removed from the tooth after the fracture of the

1. Unitek Corp., Monrovia, California.
2. Whaledent International, New York, N.Y.
cement bond.

It is quite clear from these studies that retentive force increases with the degree of parallelism and the surface contour of the post system. The retention provided by a screwed system far outstrips the retention provided by a cemented system, and this system has in fact been utilised in the Kurer Stud attachment system,\(^1\) which incorporates a stud onto a Kurer post, described by Kurer (1979). In all cases except for the shortest tapered posts, it seems that post retention far exceeds the retention required to resist the breakaway loads of most precision attachments. However, on the basis of the "locking on" principle described in the experimental component of this thesis, even 8mm tapered smooth posts may not provide enough retention to resist dislodgement.

The effect of surface serrations on the retention of the post is best explained by Colley et al. (1968) who explained that bridges of cement are allowed to form between the serrations and the rougher internal surface of the root described by Wood (1983). It is these bridges, which must be crushed, that allow the greater retention. As the cement remains both on the post and in the tooth, the site of failure is within the cement. Tapered dowels, however, tend to dislodge from a tooth cleanly, indicating that surface roughness has less effect in a tapered situation. This may be supported by Smith in 1970 showing that the surface roughness of dentinal preparations with 7° of taper did not significantly affect the retention of the castings. This is not supported by Jørgensen (1955), who feels that surface roughness on the casting, not the tooth, significantly increases the retention of every degree of tapered crown up to 45°.

Tapered posts compared to parallel sided posts have been

discussed by a number of authors. Results using tapered post systems appear to be successful although generally more anecdotal. For example, Gerstein and Burnell (1964) describe a group of 60 tapered Kerr Endowels 1 cemented for 6 months with no failures. Although custom made posts are advocated by some authors, for example, Perel and Muroff (1972) due to the accuracy of fit of the post in the tooth, it is generally supported that well fitting prefabricated post systems offer the best retention properties, by authors such as Colley et al. (1968) and Henry and Bower (1977).

Taper, as seen by Jørgensen in 1955, had much to do with retention. Retention, he found, increases exponentially as zero taper is approached. Studies on retention in relation to taper in crowns, discussed by Jørgensen and later analysed in detail by authors such as Hegdahl and Silness (1977) and Nicholls (1974) can be applied to the retention of posts within teeth. Also Courtade and Timmermans (1971) have documented that pins exhibit the same retentive characteristics.

b) Post Length

The retention of posts increases with an increase in length primarily due to an increase in surface area. Colley et al. (1968) noted a proportional increase in retention as related to length, particularly in parallel sided posts. Tapered posts gained less retention with an increase in length due probably to a diminution of the total surface area because of the narrowing of the tapered dowel. Although a 12.0mm length post has been recommended by Duckmanton and Taylor (1975c), few studies have been carried out on dowels longer than 10.0mm. Standlee et al. (1978) agreed with Colley et al. that increased length increased retention when comparing 5mm and 8mm posts with the

exception of small tapered dowels and serrated dowels cemented with carboxylate cement.

Johnson and Sakumura (1978) however, discovered some interesting results when length was varied. They found that increasing a 7mm dowel to 9mm adds little to retention whilst increasing a 7mm or 9mm dowel to 11mm increases the retention by 24-30%. The authors believe these results support the contention that posts should occupy half the root length if the root is not long enough to accommodate a longer post as no advantage in retention is gained by adding the extra two millimetres to only achieve a 9mm post. However, an 11mm dowel provides a significant increase in retention and should thus be used for maximal retention when conditions permit. Even though retention increases of this magnitude exist when diameter is increased, the preferable method to increase retention is to increase the length of the dowel and thus preserve dentine and the body of the root.

c) Post Diameter

The diameter of posts is one of the critical factors in post design, due to the importance of the width of the post in relation to root morphology. Trabert et al. (1978) found that a major cause of the failure in posts was related to the width of the post. This was due mainly to the risk of root fracture or perforation by using posts of too large diameter in root canals.

These risks must be weighed against the function to which the coronal restoration is subjected. The post must not only be within the bounds of adequate supporting tooth structure, but must also be thick enough to be rigid enough to withstand the forces to which it is exposed. It is generally accepted that there is adequate tooth structure remaining if the post occupies one-third the diameter of the
available root. However, in some cases the external anatomy of the roots of some teeth and the internal access for preparing post holes is such that the risk of causing perforations in these canals is quite large. Particular teeth of concern are:

1) Lower anteriors which have very fine roots.

2) Lower first bicuspids teeth which have very definite dumbbell shaped canals which are easily perforated when using a circular drill centrally.

3) Upper first bicuspids teeth, particularly the buccal root which often appears to have a lingual groove which is easily perforated.

4) The mesial roots of the lower molar teeth which, due to their curvature and access, are easily perforated on their distal aspect.

5) The upper molar teeth whose distobuccal roots are easily perforated on the mesial aspect for the same reasons.

Although Kurer (1977) and Standlee et al. (1978) both agreed that the diameter has little significance on the retention, it seems unusual that the increase in surface area would not have an effect on the retention in a similar way in which the surface area has an effect in crown retention, as described by Gilboe and Teteruck (1974) and Kaufman et al. (1961). Indeed, Johnson and Sakumura (1978) found that increasing the diameter of dowels produced an average 24% increase in retention by increasing tapered posts from size 80 to size 120 or by increasing parallel dowels from 0.036-inch to 0.050-inch diameter. However, their recommendation was to increase length rather than diameter, to enable an even better benefit due to the loss of strength in the dentine of the root by increasing diameter. Indeed, photoelastic analysis by Henry
(1977) and Standlee et al. (1972) indicate the effects of an increased width of posts on the remaining tooth structure is the greater likelihood of root fracture. This may be particularly significant in the light of the study by Mattison and Fraunhofer (1983) showing that stresses in a lateral direction which could apply in the overlay denture situation are particularly emphasised when wide posts are used. Restricting post diameter conserves tooth structure and substantially reduces internal stresses within teeth that have cast posts.

It is also true to say that most studies on retention of posts have been done by testing retention in only one direction - axially - and that all teeth have been either mounted in acrylic blocks or in plaster blocks, all of which must have a supportive effect on the tooth root, preventing fracture. Kurer (1977) even uses whalebone blocks for his retention studies which would give absolutely no indication as to the toleration of the roots to this form of preparation. A study by Durney and Rosen (1977) found that root fractures began to occur at 22 ounces/force (0.154 Nm) for Dentatus posts and they found that no roots were fractured with a Kurer tap to 30 ounces/force (0.21 Nm). This was, they believed, due to the fact that the Dentatus post is tapered and exerts an expanding force on the root. As they admit there may be a significant difference to these results if the roots have been non vital and root filled for some time and roots imbedded in stone blocks, even coated with a silicone impression material may be supported by the stone to reduce the breakage percentage. Henry's (1977) observations that the Kurer posts exhibited stress concentrations within the root even without loading seems to suggest that incomplete debridement of the screw channel may be responsible for the stress concentrations within the

root. Also a screw tap must blunt to a degree, particularly at the cutting tips leading the tap to eventually cut an undersized hole for the following posts.

d) The Cement Type Used

As described by Stevens in 1975, a dental luting cement should be compatible with tooth tissue, should provide a joint of sufficient strength to withstand the forces of mastication, should fracture slightly below the strength of tooth structure, should prevent marginal leakage and protect the tooth against further decay adjacent to the margin of the restoration. Additionally, it should be noted that a cement used to retain an overlay denture attachment coping should have sufficient strength to resist the additional forces applied to it during function. Unfortunately, dental cements do not meet all these criteria and each cement must be considered in its own right for the purpose to which it is needed.

Cements that may be considered include:

i) Zinc Phosphate Cement

This cement has been used in dentistry since 1879 a Dr. Pierce first demonstrated its properties to a group of Pennsylvanian dental surgeons. Zinc phosphate cement has changed little since then; it is basically zinc oxide with some other modifier oxides, notably magnesium oxide and an aqueous solution of phosphoric acid buffered by aluminium and zinc salts. The setting reaction results in the formation of $\text{ZnHPO}_4 \cdot \text{3H}_2\text{O}$ or $\text{Zn}_3(\text{PO}_4)_2 \cdot 4\text{H}_2\text{O}$. The properties of zinc phosphate cement depend considerably on the manipulative variables. Eames et al. (1977) studied the working times and resultant film thickness of zinc phosphate cements and found that powder/liquid ratios and mixing time of cements should be measured and standardised to ensure adequate working time and
acceptable film thickness and thus complete seating of the dental casting, due to the high variability in these factors with arbitrary mixing.

Indeed, a 1% change in the water content of the liquid reduces the compression and tensile strengths of the cements by approximately 5%, which could easily occur by simply placing the liquid on the glass slab too long before mixing, according to Norman et al. (1970).

Jørgensen and Holst in 1967 found that the crushing strength of the cement is the key factor in the determination of retention. By a variation in the powder/liquid ratio, the crushing strength of the cement was altered and the retention was found to increase (see Figure 13.1).

Although the film thickness may have little effect on the retention of the casting, according to Jørgensen and Esbensen (1968), the filtration effect which occurs in a non vented casting, as shown by Jørgensen in 1960, promotes an area of much lower powder/liquid ratio, and an increase in film thickness at the margin. As shown by Dimashkish et al. in 1974, this increased film thickness could result in a susceptible margin, particularly when breakdown is caused through a combination of solubility, diluted organic acids and abrasion, as discussed by Norman et al. (1969).

The principle advantage of zinc phosphate cements is their good manipulative characteristics and their good strength characteristics when compared to other traditional cements, as reported by Stevens in 1975.

ii) Hydrophosphate Cement - is basically the same as zinc phosphate cement except dihydrogen phosphate has been added to the cement powder to replace the phosphoric acid, which is the susceptible ingredient to water absorption. Simple distilled water is added to the
Figure 13.4: Retention Plotted Against the Crushing Strength of ZnPO₄ cement
powder to produce a zinc phosphate cement. Although shelf life is improved, the cement has, according to Going and Mitchum (1975), the disadvantage of weak compressive strength, high solubility, low pH and a film thickness of above 40 μm.

iii) Copper Cements - which are not generally used today, are modified zinc phosphate cements, to which copper oxides or copper salts are added to the zinc phosphate cement to produce an antibacterial effect.

iv) Silicophosphate Cements are essentially a silicate cement to which 10% zinc oxide has been added, mixed with phosphoric acid. According to Eames et al. (1977) and Hembree et al. (1968), although the strength properties are better than zinc phosphate, their manipulative problems tend to promote an unacceptable film thickness, which has led to the cements not being very popular. However, the properties of lower solubility and the slow release of fluoride into the surrounding tooth structure does offer some benefits.

v) Zinc Oxide and Eugenol Cement. Pure zinc oxide and eugenol cement is basically unsuitable for permanent cementation due to its poor strength (1,000-4,000 psi compared to 12,000-15,000 psi for ZnPO₄ in compression), low abrasion resistance and leaching of eugenol from the matrix, as described by Going and Mitchum (1975).

vi) Reinforced Zinc Oxide/Eugenol Cements. Modifications to the traditional zinc oxide eugenol cement occurred in the early 1960s, culminating in a cement containing zinc oxide, hydrogenated resin and aluminium oxide and EBA-eugenol liquid. The aluminium oxide replaced fused quartz in this cement and was found to improve the mixing properties, film thickness (26 μm) shown by Brauer et al. (1968) and compression strength up to 15,000 psi. Solubility and disintegration
are as low as 0.03%. More recent studies have cast doubt on the film thickness characteristics of these cements (Hembree et al., 1978) and their clinical durability (Richter and Veno, 1975), leading us to question their long term clinical performance.

vii) Polycarboxylate Cements. Smith in 1968 introduced a zinc polyacrylate cement later named polycarboxylate cement, which consisted of zinc oxide (90%) and magnesium oxide powders (10%) and a 40% aqueous solution of polyacrylic acid. The cement is unique in that it is specifically adhesive to tooth structure, because polyacrylic acid chelates with the calcium component of the tooth, particularly enamel, as shown by Beech in 1973. Manipulative variables depend on water, evaporation of water from the liquid causing an increase in the film thickness, as shown by Kafalias et al. (1975). Unfortunately, although polycarboxylate bonds to tooth structure and some metals, for example, stainless steel, it does not bond to gold, shown by Stevens (1975), hence retention characteristics are related to the design of the casting. Standlee et al. (1978) noted that the effect of the cementing medium on post retention was statistically insignificant except in the case of smooth tapered gold posts, where there is a significant increase in retention from zinc phosphate cement compared to polycarboxylate and epoxy cements. This is probably a combined effect of non adhesion to gold and lack of serrations which would physically hold the polycarboxylate to the post. Methods for improving the bonding of polycarboxylate to gold have been developed, for example McLean's work in 1977, with the tin plating of precious metal restorations, which promotes a wetting of the restoration surface and a bond approaching the "physico-chemical" bond to tooth structure.

viii) Resin Cements. Methyl methacrylate (PMMA) cements had some interest in 1955 by Schwartz and Phillips, but due to loss of adhesion
in wet conditions were found to be unsuitable, for example, CBA No. 9080 based on composite resins which, whilst having excellent crushing resistance as described by Wood (1983), they have poor film thickness and are no stronger than ZnPO₄ in normal cementing situations.

ix) Glass Ionomer Cements. As described by Hotz et al. (1977), these cements, set by a hardening reaction between an aqueous solution of homo or co-polymers of acrylic acid and a powdered calcium alumino-silicate glass Al³⁺ and Ca²⁺ ions, are extracted from the powder by the polyanions of the acrylic acid. Setting results from the formation of a calcium polysalt gel matrix after unwinding of the molecular chains due to the mutually repulsive electrostatic forces of the ionised carboxylate groups. The gel becomes elastic at first, then hardens with the reinforcement of the aluminium polysalt.

Whilst manipulation variables are critical, glass ionomer cements do display good properties. Film thickness is around 25 microns, they have a low solubility, they have some degree of translucency, they adhere to dentine and have a high compressive strength. They also have some cariostatic properties due to their slow release of fluoride into the surrounding tooth structure, as discussed by Wilson et al. (1977).

Adhesion to tooth structure, particularly non vital dentine, is best aided by pretreatment with citric acid (Hotz et al., 1977), and possibly by a mineralising solution (Levine et al., 1977). As with polycarboxylate cements, glass ionomer cements do not bond to precious metal or porcelain and may need to be thinned to provide the polar surfaces for physiochemical bonding, according to Maclean (1977).

 Auxiliary Factors in Post Retention

e) Accuracy of Fit of the Post

As described by Perel and Muroff (1972), proper internal
adaptation of the post distributes the internal stresses of its circumference as evenly as possible without undue stress at any one place and it allows for only a thin, even layer of cement seal. As noted by Colley et al. (1968), maximal retention is only achieved if the post fits the root canal. Improperly fitted posts are surrounded by thick layers of cement in which numerous voids may be present, obviously reducing retention. Gutman (1977) aptly describes that the post shape should be a reflection of the root canal morphology, often necessitating the custom forming of the post.

f) **The Presence of Venting**

As we know from Jørgensen's work in 1960, the taper angle of the preparation affects the spread of cement. Taper angles of less than 10° restrict the flow of cement and causes an increase in the film thickness of the seated casting and a filtration effect, which alters the powder/liquid ratio of the cement. Jørgensen's work shows that venting a casting can reduce the film thickness drastically. Even though he later showed that film thickness does not have too great an effect on retention, a large discrepancy (from 20 micron to 140 micron) does alter retention by 30% (Jørgensen and Esbensen, 1968). More importantly, improper seating of the casting leaves the tooth root susceptible to secondary caries, due to the breakdown of the cement margin. Indeed, this has led Kaufman et al. (1961) to suggest the routine use of perforation to achieve maximal retention and optimal coverage.

It could be argued that a root cap requires an allowance for venting in three areas of its design (see Figure 13.4).

1) The post requires a venting channel if the post taper is less than 10° to allow cement to flow out from below and prevent hydrostatic pressure build up.
Figure 13.5: The Filtration Effect During Cementation of a Root Cap
ii) The seat area of the casting, which effectively blocks the flow of cement when the seat engages the walls of the seat preparation. This area may become critical, particularly if there has been a relatively parallel preparation.

iii) The marginal bevel area depending on the height of the bevel and its degree of taper. If a long taper exists in the preparation, a vent hole on the occlusal surface adjacent to the seat should be considered.

g) The Seating Force Used in Cementation

Again, Jørgensen in 1960 demonstrated that the film thickness of zinc phosphate cement was affected by the pressure exerted on a restoration during cementation. Forces above 5 kg had no significant effect on reducing film thickness and also the maintenance of pressures for longer than one minute had no appreciable effect. Obviously the manipulation and effect of the seating force is very much dependent on the mixing variables and the type of cement used and the viscosity and the temperature of the cement shown by Eames et al. (1977).

h) The Surface Roughness of the Casting or the Tooth Surface

The surface roughness of a casting could be divided into two types:

i) The roughness caused by the casting technique.

ii) Intentional roughening of the casting to produce mechanical retention for the cement.

i) Fusayama and Yamane in 1973 showed that all casting techniques produce surface roughness in the casting but the least is shown with steam pressure casting techniques. External discrepancies in the casting could affect retention by interfering with the proper seating of the casting and creating stress point concentrations within
the root. Porosity of the casting has less effect on retention but will produce a weakened post or casting.

ii) Intentionally produced surface roughness can be incorporated in the casting and it has been shown by Jørgensen (1955) to increase the retention of the casting significantly. However, the effect of roughness on retention is unpredictable and he cites this factor as being responsible for the high standard deviation of his data on retention related to film thickness (Jorgensen and Esbensen, 1968).

Tooth structure roughness within a range of 5 to 120 microns, does not significantly affect the retention of a completely vented casting according to Smith (1970).

1) **The Post Material**

As noted by Gerstein (1984), the metallurgic properties of prefabricated precision posts may be better than cast gold posts. Because grain size is established at the time of solidification, a large grain structure is generally detrimental to the strength properties of the metal (Skinner and Phillips, 1967). Although cast gold posts may have good ductility, weakness can occur in the grain structure which may precipitate fracture of the casting. All prefabricated posts are in effect wrought metal which have higher strength values than cast metal due to the strain hardening of the grain structure. Kerr's Endo-posts,¹ for example, display a tensile strength of 165,000 psi in the heat treated condition.

In general, cast gold root caps require precious metal prefabricated posts to allow compatibility of the two metals in the casting procedure. Coping systems which incorporate the post and occlusal

restoration in a single prefabricated unit, are not necessarily of precious metal content. Systems such as the O-50 Attachment System\(^1\) and the Zest Anchor\(^2\) use cobalt chromium alloy posts as part of their attachments.

Magnetic attachments use stainless steel posts which are incorporated in the "keeper". Corrosion of metal posts in canals must be considered in the use of non precious alloys as posts. Although stainless steel does corrode in the oral environment and in root canals, according to Silness et al. (1979), no correlation has been made to failure of posts by this manner.

13.1.1.2 Post Systems

Due to the retentive requirements of the post, customised cast dowels usually have too great a taper and are too short to be used in attachment copings. Discrepancies caused in casting a combined external crown and internal inlay type preparation can cause the dowel to be oversized and risk root fracture during cementation according to Standlee et al. (1972). The need to use a customised dowel to achieve fit within a tooth root may contraindicate the use of some more rigid precision attachments.

There are two types of post system which may be used with attachment copings -

a) Prefabricated Resin Patterns

b) Prefabricated Metal Dowels.

a) Prefabricated resin posts: These are designed to allow casting of the coping and post in one unit. Exact sized burs prepare the

1. Scodenco, Tulsa, Oklahoma, U.S.A.
2. APM-Sterngold, San Mateo, Calif., U.S.A.
channels and these are matched by the corresponding plastic burn out posts. Cast posts have only one quarter to one half the strength of prefabricated metal posts, due to the unstressed grain structure in the cast posts, as noted by Henry and Bower (1977). Resin dowel systems include:

Tapered systems

i) Parkell I.C. System$^1$ is a smooth tapered plastic post system in two sizes: a 12mm long, 1.6mm diameter post and a 13mm by 1.9mm diameter post, both having a 2° taper.

ii) Kerr Endo-Posts$^2$ - a system of calibrated plastic dowels, which are endodontically standardised to match endodontic reamers from size 80 to size 140.

iii) P.D. Points$^3$ - a tapered plastic post system, which range in six sizes from 1-6, with corresponding precision drills.

Parallel systems

iv) Whaledent Parapost System$^4$ incorporates a range of plastic burn out posts which are cylindrical, serrated, vented and available in 5 sizes - brown (0.036"), yellow (0.040"), red (0.050"), black (0.060") and green (0.070").

b) Prefabricated metal posts: These have the advantage of strength, due to their wrought metal construction. The corresponding reamers allow an exact fit in suitable roots and require only minimal enlargement of the canal space due to their high strength. The posts are

1. Parkell, Farmingdale, U.S.A.
3. Produits Dentaires, Very, Switzerland.
generally made from high fusing metal to enable cast on or soldering procedures, but they must be reheat treated to regain the physical properties.

Prefabricated metal systems include:

Tapered posts
i) Mooser Posts\(^1\) - a 5° tapered post available in smooth, or sand blasted finishes, with four different head styles, four different length and diameter sizes, and made in either Pivitor or Ceramicor metals.

ii) Stutz Pivot\(^1\) - a 2° tapered post which is cemented into a serrated silver shell, 10.5mm in length and 1.7mm diameter. The post is made up to 18.35mm in length and is 1.6mm diameter. The purpose of the silver shell is to provide a double seal for the root canal and a metal surface for cementation. Soldering of the coping to the post is recommended due to the double cement layer. The posts are provided in either Pivitor or Ceramicor.

iii) Kerr Endoposts\(^2\) - the mate to the plastic dowels, these high fusing alloy dowels match endodontic reamers from no. 80 to 140. The notched head allows addition of pattern resin for the direct fabrication of the coping.

Parallel posts
iv) Paraposts\(^3\) - made in high fusing gold alloy, they are suitable for root caps, either as a coping cast on or by soldering. These parallel posts are vented and come in 5

colour coded sizes, as with the plastic posts. Retentive and stress distribution characteristics of these posts make these posts a highly popular choice. Auxiliary equipment includes a paralleling jig for placement of parallel posts and a pin jig for placement of auxiliary pins. A modified post suitable for anterior teeth is the Triax System which is only available in stainless steel and titanium.

v) Cendres-Métaux Serrated\(^1\) wire is supplied as long lengths of serrated, vented gold wire (Pivitor) in similar sizes to Parapost dowels. The advantage is that the wire can be cut to the desired lengths without wastage.

vi) Sargenti Posts\(^1\) - cylindrical sandblasted posts available in two sizes: 12.3mm long and 1.3mm in diameter, and 15mm long and 1.5mm in diameter. The posts have no vent and therefore would cause considerable back pressure during cementation.

vii) Schenker Step Pivot\(^1\) is a parallel post which takes into account the normal taper of roots. The post is a sandblasted smooth finish with a venting channel and it is supplied in two sizes: a medium 1.4mm diameter and a large 1.9mm diameter post bore 15mm long. The shape enables a longer post to be placed without perforation of the root to give excellent retention. It is available in either Pivitor or Ceramicor metals.

Screwed posts - These posts are designed to provide mechanical fixation in addition to cementation. Two screw posts may be suitable to

retain precision attachment copings, however, the stresses that occur on cementation may risk root fracture, as discussed by Henry (1977) and Standlee et al. (1972).

viii) Kurer Screw System\(^1\) utilises a tapped S shaped thread which allows the post to be screwed down during cementation. The post has been incorporated with a stud attachment which can be screwed down onto a coping or simply flat onto a prepared root face.

ix) VK-Screw (Markowitsch Screw).\(^2\) A similar system to the Kurer screw in that the screw is tapped into the root dentine but has a Z shaped thread. The system has two widths of post: 1.5mm and 2.0mm and the length ranges from 14.3mm to 18mm. Use of this system is generally combined with bar attachment fixation or an eccentrically placed attachment. The retention provided may be wasted if an attachment cannot be used due to lack of space on the root cap.

13.1.2 The Internal Seat

The internal seat in attachment copings as described by Mensor (1975) and Duckmanton and Taylor (1975e) fills a number of requirements.

1. It provides sufficient metal underneath the precision attachment to prevent perforation and distortion during the soldering operation.

2. It increases the strength of the coping in this area.

3. It provides resistance form against rotation.


2. Cendres and Métaux, Biel-Bienne, Switz.
4. It provides localisation of the coping during cementation. Mensor (1975) describes the internal seal area as a simple hollowing out of the area under the attachment. Duckmanton and Taylor (1975e) describe the eccentric locating seat at 1.0-2.0mm deep with minimum taper with the facio-axio surface angle and the post-seat floor surface angle well rounded to prevent stress concentrations by changes in cross sectional area and to facilitate fitting of the casting. Jumber (1981c) described the internal seat as a one millimetre indentation in the form of an "X". This design however, does not provide an even thickness of coping and could cause distortion on soldering.

In a discussion on retention and resistance form of castings, Gilboe and Teteruck (1974) describe resistance form as the shape that counteracts shearing stress and retention form that which counteracts tensile stress. The primary factor in resistance form is the axial surfaces of the preparation and the secondary factors are provided by grooves, boxes and pinholes.

Considering compressive loads on castings in the order of 133 pounds can cause tensile stresses to be focused at cervical margins according to Craig et al. (1967) and the fact that the relative stiffness of the casting plays an important role in this effect, as described by Yettram et al. (1976), maximal rigidity in this area seems to be paramount.

Although the internal seat would also have some role to play in retention, it makes no statistical difference to direct retention over a simple post of the same length, according to Reisbick and Shillingburg (1975).

13.1.3 The Chamfer Margin

Due to the requirements of the coping for space within the
denture, the chamfer margin will in most cases be very short. Preparation of this area of the abutment has been described by Duckmant and Taylor (1975e) as simply achieved by establishment of a 10° chamfer and then reduction of the root face until the chamfer is 1.0mm in height. Jumber (1981c) suggests that the preparation should not follow the gingival margin if there is significant bone loss lingually. Facially, reduction must be sufficient to allow room for the setting of teeth, particularly in the upper anterior region. He suggests the short proximal walls should be as parallel as possible to provide as much retention as possible and the margin is finished with either a feather edge or chamfer.

Stress analysis on castings by Yettram et al. (1976) and Gilboe and Teteruck (1974) suggests that the casting should be as thick as possible at the margin to prevent distortion on loading, and as parallel as possible to aid in retention form, which makes up for lack of height. When forces are applied at an angle to the tooth axis the restoration tends to be displaced by rotation. Rotation force is opposed by surface areas of the preparation, or rather by the cementing medium on the side of the preparation where the force acts. The casting will be pressed against the preparation or the luting cement only in a part of the surface area of the preparation. Elsewhere, the rotating force will tend to lift the crown away from the preparation, as described by Hegdahl and Silness (1977). The actual stresses are much greater than those calculated by dividing the applied load by the entire resisting surface area. Initial failure occurs at stress concentration points, where cracks form, which eventually enlarge until complete retention is lost according to Nicholls (1974). Hence, the chamfer area of the preparation plays a key role in the maintenance of the marginal seal and in retention. These studies have been done of course on rotational
forces which would apply in precision attachment copings. In the case of magnetic keepers, the Gillings\textsuperscript{1} and Jackson\textsuperscript{2} designs allow no chamfer provision. The effect of loading on this design depends on the shape of the keeper. A flat surface, which provides for some freedom laterally, would not convey a torquing force to the keeper under normal occlusal forces. Consequently, forces would act axially on the keeper and marginal integrity would depend on the crushing resistance of the cement medium. Higher torque would occur in a dome shaped keeper as it would provide more resistance to lateral forces. Thus a dome shaped magnetic keeper would appear to require a chamfer margin to resist cement breakdown and failure.

13.1.4 Accessory Pins

In cases where only a short post is possible in an abutment requiring an attachment coping, Jumber (1981f) suggests the post and pin combination to improve retention. The main requirement for pin additions is that all pin holes and posts must be parallel to each other and there is adequate room. As described by Gilboe and Teteruek (1974), pins are a secondary factor in resistance and retention form and are the best factor to add when there is inadequate resistance and retention because of lack of length in the preparation. Studies on pin retention by Lorey et al. (1967) and Moffa and Phillips (1967) tell us that,

a) Threaded wrought pins are more retentive than smooth cast pins, provided the pin length exceeds 1mm.

b) There is a direct relationship between both pin length and retention and pin number and retention.

1. Innovadent, Pymble, Australia.

c) There is no difference between the retentive influence of three and four pins when pin diameters of 0.55mm and 0.65mm are used.

d) There is no difference in the retentive ability of pin diameters of 0.55 and 0.65mm until the pin length is 3.0mm or unless five pins are used.

e) There is a significant increase in retention as the pin diameter is increased from 0.55mm to 0.75mm. The 0.75mm diameter pin has the greatest retention for all combinations of pin lengths and numbers.

f) Flexibility of castings plays a role in the retention of pin. A casting which is too thin near a pin can allow flexion and distortion possibly causing one pin to fail and break the seal.

g) Retentive values on single pins in particular are very variable, therefore, to rely on the use of pins alone for retention may be a hazardous procedure according to Burns (1965).

13.2 The External Design

The external design requirements for attachment copings are:

a) To allow cleansibility for periodontal maintenance and caries control.

b) To provide a horizontal platform for the soldering of the precision attachment in the correct alignment.

c) To be the correct height and contour to allow the retention of the precision attachment within the confines of the denture base and for the placement of the artificial teeth.

d) To provide the correct contour to distribute the forces applied to it from the denture favourably in order to protect the supporting tissues.
a) As described by Jumber (1981b), the copings should never be over-contoured with excessive undercuts which would only encourage tissue proliferation. Mensor (1975) describes the coping as having a gradual gingival bulge to protect the marginal gingiva. Difficulties in providing good embrasure spaces occur when using splinted copings and bar fixation. The coping needs to be sufficiently high to allow a space for cleansing instrumentation. As described in the next chapter on periodontal considerations, the gingival margin should be finished supragingivally.

b) The attachment coping should be waxed thickly enough to enable a horizontal platform to be milled on the occlusal surface. Once checked for fit, a localising impression is taken, which allows determination of the most suitable path of insertion for the prosthesis. The castings must be checked well to maintain adequate thickness of metal 0.5-1.0mm during the milling procedure. A flat surface is created on the coping, preferably lingually, to allow room for the setting of teeth over the attachment and housing. As described by Duckmanton and Taylor (1975f), considerations to be observed in relation to soldering are

1) The path of withdrawal of the anchors should be as close to parallel as possible.

2) The thickness of the solder should be ideally only 0.1mm for maximal strength.

3) Solder must be prevented from flowing onto the working surface of the attachment.

4) The root cap should be between 0.5mm and 1.00mm thick.

5) Due consideration should be made to the path of insertion which is made from a consideration of tissue undercuts, tooth contour and artificial tooth placement.
Some attachments, such as the Rothermann\(^1\) and the Ceka 691,\(^2\) have solder already incorporated, but most attachments require the use of soldering mandrels to either direct solder in a surveyor or invest and solder in a furnace.

c) An important consideration in the contour of the coping is the placement of the precision attachment and the aesthetic requirements of the final prosthesis. If the platform is milled with too labial an inclination, the housing of the attachment may show through the labial face of the denture tooth. Assessment of tooth contour is important before the final contour of the attachment coping is established. An occlusal rim is used at the coping tryin to establish

   i) labial contour for the teeth
   ii) vertical dimension
   iii) the occlusal plane.

Thus provided with an indication of the height and contour of the available space, a choice can be made as to the type of attachment which would be most suitable. Height and width characteristics of the attachments are provided for most attachments by the manufacturers. In cases of short vertical dimension, the acrylic base may impose on lingual tongue space, or be observable above the occlusal plane if too large an attachment is used.

d) As described in the previous chapters, precision attachment can potentially allow forces to act on the abutments which can damage the supporting structures. Potentially damaging forces which may be influenced by coping design are:

i) Torquing forces which could be applied to the abutment under vertical load—a coping requires relief in keeping with the vertical resilience designed into a particular precision attachment. Relief is provided by correct spacer placement during processing.

ii) Torquing forces which could be applied to the abutment on removal of the prosthesis from the mouth—if an undercut to the path of withdrawal exists on the labial or lingual surface of the coping, it will cause torquing, and "locking in" of the denture will occur. This will either result in damage to the periodontium or the root or eventual removal of the coping from the root.
CHAPTER 14

PERIODONTAL CONSIDERATIONS

14.1 Introduction

The success of overlay denture therapy depends on maintenance of the periodontal health of the abutment teeth. Stahl (1973) describes gingival disease as characterised by changes in colour, bleeding, exudation, retraction of the gingival margin, loss of form, and later by loss of stippling. Microscopically the gingival fibres are destroyed initially in the middle sector fibres, directly subjacent to the epithelial attachment, followed by dense inflammatory infiltration of the gingival corium, progressively replacing the connective tissue gingival fibres. Deepening of the pocket occurs with migration of the epithelial attachment apically along the cementum, accompanied by separation of the gingiva as a result of inflammation.

Preparation of the mouth for overlay dentures necessitates the resolution of periodontal disease. However, even where this is not possible, overlay dentures are valuable for use as "interim" or training dentures as described by Smith (1974), Fenton (1976), Ettinger (1977) and McDermott and Rosenberg (1984). Long term retention of the abutments in a healthy state, depends upon a thorough examination using a periodontal probe to determine pocket presence and architecture (Figure 14.1a), radiographs (Figure 14.1b), notation of tooth mobility, tissue texture and colour notation, and the presence and extent of bleeding or exudate. The quality and quantity of the attached gingiva is also an important consideration. Robbins (1981) feels that this barrier should be intact on all surfaces to protect against the insults to which the gingival cuff is submitted from overlay dentures. Lang and Loe in 1972,
PERIODONTAL ASSESSMENT BY PROBING AND X-RAYS

Figure 14.1a and b: Periodontal Assessment by Probing and X-Rays
found that when less than 1mm of attached gingiva was present, chronic inflammation was evident, even in the absence of bacterial plaque. Also Robbins (1981) states that it may be a contra-indication to have abutments too close to one another – if the tissue lacks keratinisation, tissue strangulation can occur.

According to Jewson (1975) and Hall (1980), selective extraction of the teeth should occur early in treatment, when a diagnosis as to the prognosis of the teeth has been established. Reasons include the fact that the healed tissues can lend support to the prosthesis and the removal of hopeless teeth may facilitate the healing of less compromised teeth.

An understanding of the clinical implications of tooth mobility is important. Perlitsh (1980) describes the concept of "critical mass", whereby the loss of alveolar support increases with the depth of the pocket. The apical third of a tapering root may only consist of 15-20% of the total surface area of the root. Once bone loss occurs to this level, the horizontal loading creates a zone of combined pressure and tension both at the crestal level and at the apical area, which means the whole periodontal ligament becomes subject to haemorrhage and thrombosis, with degeneration and necrosis of the ground substance and collagenous fibres of the ligament. Consequently, the entire remaining intra-alveolar supporting bone is resorbed. Consideration of this process must be taken into account in regard to the effect crown shortening has on the root to crown ratio and the beneficial effects of periodontal treatment. Obviously teeth which would normally have reached this "critical mass" stage when they are of normal height can be retained simply by the improvement of the root to crown ratio.
14.2 Periodontal Treatment

Preparatory to the operative phase, periodontal therapy to eliminate the pockets and provide adequate attached gingiva must be complete. Robbins (1981) describes the surgical methods available for pocket elimination. He describes the gingivectomy, which can be used where there are no intra bony pockets and there is an adequate band of attached gingiva. Surgical curettage and reattachment procedures, for example the Modified Widman Flap are described as not very suitable due to their reliance on a rather friable connective tissue attachment. These approaches may be more suitable when aesthetics in crown and bridgework are essential. As the mucosa under a denture tends to be less keratinised and the stratum corneum is thinner (Watson and MacDonald, 1982), a long junctional epithelial attachment, which is achieved in reattachment procedures may be unsuitable. Apically positioned flaps appear to be the preferred choice of surgical procedures to eliminate pockets for overlay abutments. This results, postsurgically, with a shallow sulcus and a physiologically sound attachment apparatus.

Establishment of an adequate zone of attached gingiva depends upon the width of the keratinised gingiva. If it is adequate, the apically repositioned flap will maintain the thickness of the attached gingiva. If there is too little keratinised tissue a free gingival graft procedure, as described by Corn (1973), should be used to augment the attached gingiva. Care must be taken with the patient's denture to prevent any impingement on the base on the graft, which can cause dislodgement of the graft in the first days after healing.

Maintenance of the teeth before operative procedures are complete are different to those which will eventually be used. Stabilisation of the abutments may be necessary in the short term using splinting, which
prevents occlusal overloading of the abutments and facilitates cleaning as described by Jumber (1981h).

14.3 The Effect of Overlay Denture Treatment on the Periodontal Condition

Reviews of the periodontal condition of overlay denture abutments have been numerous. Most studies have dealt, however, with the effect of overlay dentures on unrestored root faces. Studies include that of Ragnarson et al. in 1963, who recorded 50% carious breakdown of abutments after 5 years, Rantanen et al. in 1971 and in 1976, which demonstrated periodontal breakdown in 90% of abutments after 3 years. These studies give the worst results but they are in fact the only studies done where attachment fixation was included.

Ralph and Murray in 1976 produced somewhat better results, Reitz in 1977 and again in 1980 reported an exceedingly high incidence of periodontal pathology (59.2%), but on the other hand, Fenton and Hahn (1978) reported that overdenture abutments showed no significant differences in pocket depth, plaque retention or gingival inflammation. The validity of this study may be in doubt, because of differences between the samples studied and the types of functional loading according to Davis et al. (1981). Crum and Rooney (1978) found in their 5 year study that alveolar bone loss is eight times less than normal alveolar bone loss but this bone loss corresponded to the periodontal bone loss resulting in reduced sensitivity and discrimination and no canine response. Davis et al. (1981) found that overall, overdenture abutments showed no significant increase in pocket depths or loss of attached gingiva. They did find that mandibular teeth however, were at a much greater risk than maxillary teeth of developing periodontal pockets and losing attached gingiva. This was particularly true of
mandibular canines (see Figure 14.2 of a mandibular canine abutment).

Renner et al. (1982) agreed with Davis et al. (1981) regarding the periodontal status of maxillary teeth and found there was no significant difference between the health of "relieved" and "non relieved" abutments. They also found that the microflora around the gingival margins varied at times from Veillonella, Actinomyces, Bacteriodes and Candida to Fusobacterium, Treponema, Selenomonas and Streptococcus, all without necessarily demonstrating any clinical sign of periodontal breakdown.

Graser and Caton in 1983 felt that there was no significant difference in the periodontal status of any different shape of root as long as it was plaque free. Dome shaped abutments as recommended by Davis et al. (1981) did provide easier setting of the artificial teeth in the denture bases.

Toolson et al. in 1982 found no significant increase in the periodontal status of the abutments, however in 1983 he found that although the pocket depths remained good, there was a significant loss in attached gingiva in the 2 year-5 year range. Toolson et al. (1982) and Derkson and MacEntee (1982) disagree as to the effect of fluoride gels on the gingiva. Toolson et al. saw no significant difference whilst Derkson and MacEntee found significantly less plaque accumulation and gingivitis.

All the above studies were done unfortunately utilising abutments on the whole restored by simple amalgam plugs. Rantannen et al. (1971) is the only comprehensive study to date, which deals specifically with attachment overdentures and therefore must be considered as a significant study.

Ettinger et al. (1984) did look at metal copings with and without attachments which amounted to 12.6% of the total number of abutments and
Figure 14.2: Gingival Recession Caused by Plaque Accumulation and Denture Pressure
were not considered separately. However, in this study 94% of abutments required periodontal treatment of some kind after 5 years, 14.3% requiring periodontal surgery.

14.4 Periodontal Requirements

Robbins (1981) outlines the requirements for the periodontal maintenance of abutment teeth.

1. A minimum of 5mm of alveolar bone is left to support the overdenture abutment after pocket elimination.

2. An adequate amount of good quality attached gingiva remains around the abutments.

3. Adequate keratinised tissue exists between adjacent abutments to prevent tissue strangulation.

4. Tooth mobility is minimised.

5. The shape of the abutment is correlated to its condition. A dome shape minimises stresses and maximises support for the denture - gold copings may not be necessary on sound tooth structure for periodontal good health.

6. Maintenance procedures must be followed, i.e.

a) 3-4 monthly recalls for examination, prophylaxis and fluoride.

b) patient compliance with oral hygiene regimen.

i) brushing technique - scrub

sulcus technique

ii) internal denture cleansing

iii) stannous fluoride gel placement.

c) Checking of the internal denture base for signs of impingement on the gingival tissues.

Jewson (1975) also suggests that consideration be given to the
angulation of the tooth to be used for an abutment. To distribute forces adequately to the root, it should ideally be in an axial position, perpendicular to the direction of the occlusal forces, in such a manner that those forces are absorbed by the oblique group of fibres.

Jewson (1975) also discusses the relative merits of the positions of teeth on the ridge. He states that bicuspids, even though they do not have a large surface area of periodontal attachment, may be a preferable abutment due to the fact that they are in the middle of the ridge. This, he believes, is beneficial because they provide support for both the posterior and anterior segments of the denture base. From a periodontal viewpoint, cuspid teeth may not be as suitable as the labial position of the cuspids often results in a fusion of their facial cortical plate of bone with the alveolar bone, thereby causing a dehiscence or fenestration, which cannot be repaired adequately by periodontal therapy and which breaks down easily if the tissue is traumatised.

The ideal overlay abutment arrangement, from Jewson's point of view, are two cuspids and two second bicuspids, which gives stability of the denture base and facilitates cleaning.

Thayer (1980) in an overview of stress analysis on the abutments by various attachment designs, deduces that periodontal health must not only be maintained by the above considerations, but also that thought be given to the types of stresses that are applied during overdenture function, which cause adverse pressure on the abutments and eventual periodontal breakdown. Indeed the significance of loading on the periodontal vasculature is discussed by Ng et al. (1981), who showed that the periodontal blood flow does decrease dramatically after loading the abutment, probably due to reactive hyperaemia in the periodontal ligament, thus compromising the blood flow to the point of making the
periodontal ligament ischaemic. Another factor which is important to note is that the more posterior the tooth, the more the vasculature of the periodontal ligament is able to recover from loading forces. This is due to the fact that the vascular density of the periodontal ligament increases posteriorly. Ng et al. (1981) feel that functionally this makes sense. If the blood vessels play a major role in tooth support, the threshold force which stops pulsation should also increase posteriorly, as this is where the heavy occlusal loads occur in a natural dentition. Consequently, from a physiological point of view, it would appear that Jewson's comments on tooth position and abutment suitability are correct.

14.5 Periodontal Considerations in Margin Placement

As a coping for an overdenture will be covered by denture base, the aesthetic consideration in the placement of a crown margin does not have any significance. The decision on the placement of the overlay denture coping should be made purely in terms of providing retention and resistance form, providing adequate height between the occlusal table and the margin for the setting of teeth and to provide optimal cleaning potential to prevent caries and maintain the periodontal health of the abutment.

Since 1968, with the work of Loe, the consensus of research has been towards the supragingival placement of crown margins. Authors including Silness (1970), Newcomb (1974) and Waerhaug (1975), believe that due to the increase in periodontal and carious breakdown rates associated with subgingival margins, all restorations should remain out of the gingival sulcus. Bergman et al. (1971) described patients treated with partial dentures after periodontal therapy, who showed no increase in caries susceptibility or periodontal breakdown, unless the
crown margins were below the gingival margins.

In the case of overlay denture therapy where the copings are covered by the denture base, it would seem that the study of Bergman et al. (1971) could be taken as significant. It would appear that supra-gingival placement of coping margins would be advisable in the light that periodontal breakdown, as described by Reitz et al. (1980), and loss of attached gingiva, particularly from mandibular teeth (Davis et al., 1981), may occur even without the teeth being restored with any form of coping.

There has never been any reference in the literature as to the finishing height of copings to the gingival margin, but it is generally stressed that copings should be contoured as low as possible to facilitate tooth and attachment placement in the denture, for example, Morrow (1975a) and Jumber (1981b). Unfortunately, the study by Rantannen et al. (1971) gave no indication as to the actual design of copings or to their placement of the coping margin and that probable effect on periodontal health.

14.6 Root Surface Caries

Caries of the root surface has been described by various authors in relation to overlay denture abutments, including authors such as Toolson and Smith (1978), Fenton and Hahn (1978), Renner et al. (1984), Reitz et al. (1977, 1980), Davis et al. (1981) and Ettinger et al. (1984). Each reported incidences of caries of 19%, 15.8%, 35.7%, 16% and 20% respectively. Ettinger et al. (1984) reported that caries incidences varied between the mandibular abutments (14%) and maxillary abutments (12.5%). Dolder (1961) reported a 10% incidence of caries in his two year old restorations in areas of gingival recession.

Root surface caries as defined by Sumney et al. (1973) is a
shallow, ill-defined, softened area, usually discoloured, and characterised by penetration and destruction of the cemental surface of the root and underlying dentine. Root caries is a process involving different organisms than those involved in enamel caries (Hazen et al., 1973). Sumney and Jordan in 1974, characterised the bacteria involved with root surface caries in humans and found that a number of different organisms were involved. They included Streptococcus mutans, Streptococcus sanguis, Streptococcus inis, some strains of Staphylococci, Neisseria sicca, and a number of strains of Actinomyces, including A. viscosus, A. odontolyticus, and A. naeslundii. Deeply within the lesion at the advancing demineralised front, the bacteria are usually gram positive diphtheroids similar to Arthrobacter. These bacteria are proteolytic and whilst not able to ferment glucose, may be involved with the extension of a carious lesion in the underlying dentine.

Histologically, a root caries lesion appears as a mat of gram positive organisms covering most of the cemental surfaces. Irregular erosive areas of cementum exist adjacent to the lesion and in some areas the cementum has been completely destroyed, exposing the underlying dentinal tubules to the invading bacteria. The organisms penetrating the dentine appear to have a filamentous, thread like morphology. A distinctive pattern of encroachment occurs in which the pioneer organisms follow the tubules, then spread laterally between the tubules, typical of the action of Actinomyces viscosus, according to Jordan and Hammond (1972). This pattern of penetration explains the gross appearance of the lesion which is not a well-defined penetrating lesion, but a softened ill-defined cavitation in the root surfaces.

As noted by Dolder (1961) and Keyes (1946), the development of cervical carious lesions was preceded by gingival recession and there is the implication that the same organisms may be involved.
Bacteriological characterisation of organisms isolated from overlay denture abutments by Renner et al. (1982) during a 9 month period found that Actinomyces and Veillonella were the predominant organisms at all times, whilst Bacteroides and Candida which were present initially, gave way to Fusobacterium, Treponema, Selenomonas and Streptococcus organisms. The presence of Actinomyces means that the potential for root caries may exist but it is dependent upon the quantitative characteristics, level of substrate and preventive measures.

Control of root caries by stannous fluoride application is noted by a number of authors, who because of its effectiveness seem to regard root caries as of minor importance in overlay dentures. These include Renner et al. (1982), Derkson and MacEntee (1982), Toolson and Smith (1983), Brewer and Fenton (1973) and Fenton and Hahn (1978). Derkson and MacEntee also believe that 0.4% stannous fluoride may reduce bacterial colonisation within the plaque in the overlay denture situation, disrupting the plaque's progress towards periodontal breakdown and root surface caries.

Another factor of significance in overlay dentures is the fact that the flow of saliva is restricted under the denture and this also has a role to play in the microflora. Regatto, as long ago as 1939, reported on rampant caries principally affecting the cervical areas of teeth and attributed this to the modification of salivary flow observed in patients after radiation therapy.

The selection of gold copings as the restoration to protect teeth thought susceptible to root caries may have been a criterion for this type of restoration, for example Davis et al. in 1981, based the decision for gold copings upon an assessment of the patient's dental
caries rate. As Ettinger et al. (1984) point out, no differences in the caries rates were noted between teeth restored with amalgam, and those restored with cast restorations. Coverage of exposed dentine with cast gold copings does not enhance caries protection. As stated by Jordan and Sumney in 1973, arresting or preventing the lesions before they become a clinical problem is far better than restoration.
SECTION 3

RESEARCH ASSOCIATED WITH THESIS ON THE DESIGN
OF ROOT CAPS FOR OVERLAY DENTURES
CHAPTER 15

THE RELATIONSHIP BETWEEN ROOT CAP DESIGN AND THE
FORCES EXERTED ON THE ABUTMENT DURING REMOVAL

15.1 Introduction

Overlay dentures can be broadly outlined in two categories:

1. Tooth supported overlay dentures.
2. Tooth and tissue supported overlay dentures.

1. Tooth supported dentures depend on the support of the available roots to provide all the necessary support for the prosthesis. This can be achieved through either root cap forms alone as suggested by Miller (1958), Morrow (1969), Kabcenell (1971) and Brewer (1973), or in combination with a non-resilient precision attachment to provide retention as well. A number of these attachments exist including the Conod Anchor, the Dalla Bona Cylindrical Anchor, the Battesti Anchor, the Gmür Anchor, the Baer Cylindrical Anchor, the Rothermann Eccentric Anchor, the Gerber Retention Cylinder, the Schneider Anchor, the Baer and Fah Cylindrical Stepped Anchor, the Ceka Attachment, the Quinlivan Attachment, the Regulex Anchor, the Ancrofix, the Anderes-Schonenburger Attachment, the Introfix Attachment and magnetic attachments including the Dyna, the Magnedent, the Gillings Split Pole Magnet, Innovadent Mini and Neo Mini magnets, the Jackson Regular and Mini Magnets.

In all these attachments except magnets, rigidity is the key
function due to the occlusal and stabilisation needs of the prosthesis.

2. Tooth and tissue supported dentures suggest that an equal amount of load is applied to the tissues and the teeth under loading—in other words the load is shared to prevent overloading of the abutments.

The overlay denture can function in this manner if space is provided in the denture to allow movement vertically over the root cap. Precision attachments designed to allow this movement in a more controlled way can also be used. Attachments designed for 'resilience' include the Rothermann Cylindrical Resilience Anchor, the Dalla Bona Resilient Ball Anchor, the Dalla Bona Resilient Cylindrical Anchor, the Bona Buffer Anchor, the Battesti Resilient Anchor, the Gerber Retention Buffer, the Biaggi Resilient Anchor, the Zest Attachment and the Mini Zest Attachment, the Ceka Attachment, the Kurer Stud Attachment, the Ginta Attachment, the B & F Resilient Anchor and the Ancrofix Attachment.

In this study I have tried to select an example of each group of attachments having characteristics which are representative of attachments of similar function. Also, it has been attempted to use attachments that are in relatively common use. The Conod attachment represents the non-resilient group which gives both a tooth supported design and rigid retention. The Rothermann Eccentric Cylindrical Resilience Anchor represents cylindrical resilient anchors. The Gerber

Buffer Attachment\(^1\) is also cylindrical but allows less rotation than the Rothermann. The Zest Anchor\(^2\) demonstrates the effect of an intraradicular attachment and also one which is flexible. The Gillings Split Pole Magnet\(^3\) is included because of its unique action in retaining overlay dentures.

The study has also included examination of an example of a plain root cap form for purposes of comparison.

Load transfer through the root cap to the tooth root has been discussed in the literature, mainly using photo elastic analysis. Thayer and Caputo (1977, 1979) found in a study on the effect of loading different attachments, that in tooth supported dentures the torquing load caused by a more positive attachment, such as the Ceka, was much greater than for a straight root cap. Henry (1977) also found that different post designs provided different forces to the roots, causing stresses on the roots that could lead to root fracture. However, loading tests may not be absolutely relevant to overlay dentures under traction. Proprioceptive discrimination by patients is a very real factor, which may limit the load on the denture and the abutments, and this is one of the main advantages of overlay dentures (Pacer and Bowman, 1975). Occlusal loading may be discernible and controllable.

More to the point is the clinical observation of failures of root cap abutments. These include:

1. Gingival deterioration - periodontal pocketing;
   - gross gingival recession;
   - gingival proliferation

2. APM Sterngold, San Mateo, Calif. U.S.A.
3. Innovadent, Pymble, Aust.
2. Root Caries
3. Tooth mobility - functional
   - periodontal
4. Cement failure and dislodgement of root cap
5. Wear of the attachment itself.

The purpose of this study was to shed some light on the mechanical factors which may affect some of these points.

Post retention was examined, as this factor is a common form of failure. The example of the failure of a root cap with a 7mm post may seem obvious, but it is common for a patient to present with a dislodged root cap (Figures 15.1 and 15.2). Duckmanton and Taylor (1975e) suggest a post length at least 12mm, 1mm wide at its tip, and initially oval in cross section. Studies on post retention by Colley, Hampson and Lehman (1968), Standlee, Caputo and Hanson (1978) and Kurer, Combe and Grant (1977), show various relative degrees of retention provided by different post designs. From Table 4, which summarizes these three studies, it is apparent that even a 5mm smooth cast tapered post will provide at least 3.5 kg of retention and this is a minimum value.

Information from Gillings (1987), Stewart and Edwards (1983) and Jackson (1986) on attachment retention figures suggests amounts, for example:

- Ceka : 840-1,000 gms retention
- Dalla Bona 604 : 400-1,000 gms retention becoming less with time
- Kurer Anchor : 300-1,900 gms retention
- and Magnets : 300-720 gms retention at least and constant.

These forces should never be sufficient to dislodge an attachment retained by a suitable post or even by a 5mm tapered, cast smooth post
Figure 15.1: Dislodgement of a Rothermann Unit with 7mm Post

Figure 15.2: Failure of this bar case was probably due to the poor attachment placement by the operator rather than too short posts
<table>
<thead>
<tr>
<th>Post Type</th>
<th>Length of Post</th>
<th>Colley et al. 1968</th>
<th>Kurer et al. 1977</th>
<th>Standlee et al. 1978</th>
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</thead>
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<td>5kg</td>
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<tr>
<td></td>
<td>8mm</td>
<td>12kg</td>
<td>17kg</td>
<td>---</td>
</tr>
<tr>
<td>Preformed Tapered Smooth</td>
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<td>8kg</td>
<td>---</td>
<td>9kg</td>
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<td>8mm</td>
<td>8.5kg</td>
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</tr>
<tr>
<td></td>
<td>8mm</td>
<td>20kg</td>
<td>19.8kg (Polycarboxylate)</td>
<td>---</td>
</tr>
<tr>
<td>Preformed Parallel Smooth</td>
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<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>8mm</td>
<td>11.5kg</td>
<td>13.8kg (10mm)</td>
<td>---</td>
</tr>
<tr>
<td>Preformed Parallel Serrated</td>
<td>5mm</td>
<td>20kg</td>
<td>---</td>
<td>24.9kg</td>
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<td>56kg</td>
<td>---</td>
<td>45.4kg</td>
</tr>
<tr>
<td>Kurer Posts</td>
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<td>64kg (6mm)</td>
<td>79.38kg</td>
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<td></td>
<td>8mm</td>
<td>---</td>
<td>106.5kg</td>
<td>86.1kg</td>
</tr>
</tbody>
</table>
(Colley et al., 1968). However, this is not clinical experience. To investigate this anomaly, a simple experiment to establish the forces required to dislodge various attachments, when combined with a root cap ridge form and denture base has been described.

15.2 Methods

As representative of each group as previously outlined, six human single rooted teeth were sectioned below the cement-enamel margins, leaving at least 14mm of root length. Preparation of the root canal was achieved by driving successive sizes of 'P.D.°1 tapered motor reamers to 12mm depth. The sides of the root were then grooved to provide mechanical retention in the acrylic block.

Using a Bachmann Parallelometer,2 the roots were mounted on the same reamer, which was tightened into the parallelometer chuck. This allowed exact vertical alignment at the post hole in relationship to the acrylic mounting block. The tooth root was then lowered (Figure 15.3) by the use of the parallelometer, into a mixed amount of clear cold curing resin,3 poured into a silicone mould and allowed to cure. Once set the mounted specimens were removed from the mould and trimmed.

Preparation of the root faces of the six teeth was then carried out along the same lines as described by Duckmanton and Taylor (1975e), providing retention for the root cap with a 12mm tapered post, an anti-rotation seat, and bevel. Exceptions to this were the Zest4 and

2. Cendres and Métaux, Biel-Bienne, Switz.
4. APM Sterngold, San Mateo, Calif. U.S.A.
Figure 15.3: Using the Bachmann Parallelogram to Align Roots in Acrylic Blocks
Magnetic attachment. On each of these preparations root caps were cast with collar forms according to Duckmanton and Taylor (1975e).

After cementation to the individual root preparations the blocks were then aligned in the Bachmann parallelogram and the copings were milled to provide a perfectly horizontal surface on the gold casting, which was in correct relationship to the long axis of the post hole.

One each of the three precision attachments; the Rothermann, the Conod and the Gerber, were then aligned using the Bachmann and their respective mounting mandrels in the same relationship to the post preparations (see Figure 15.4 a-c).

One root face was prepared for a Zest attachment using the matching drills for the post and seat preparation to provide a Zest matrix which was aligned in the long axis of the root canal (see Figure 15.4 d).

One mounted root was prepared to accept a magnetic keeper which was also aligned perpendicular to the post hole by the use of the Bachmann parallelogram (see Figure 15.4 e).

The last root was prepared for a standard root cap according to the previous design, with a flat occlusal table equivalent to the root caps used to mount the other precision attachments (see Figure 15.4 f).

An impression of each model was then taken and poured up in stone using, where available, the processing jigs used for each attachment.

According to the purposes of the experiment, wax ups were completed (Figure 15.5), an acrylic denture form was constructed over each of the models. Aluminium spacers were placed over the root faces and the attachment heads of the resilient attachments - the Rothermann and the Gerber. The Zest attachment was waxed into the fully down

1. Innovadent, Pymble, Aust.
Figure 15.5: Wax ups on Models Completed.
position. The magnet was also waxed at close contact position. The
Conod attachment and the straight root cap forms were waxed with no
spacers in place according to non resilient design.

Each denture form was provided with:

1. A loop aligned directly vertically to give withdrawal forces
in a direct line to the long axis, as previously determined by the
Bachmann parallelometer. The loop was attached by alignment in the
Bachmann.

2. A labial lifting arm to simulate forces which are applied to
the denture base behind the fulcrum line of the abutments.

3. A lingual lifting arm provided to simulate forces applied to
the denture base behind the fulcrum line of the abutments.

After waxing, each form was then processed in heat curing
acrylic, using three forms per flask (Figure 15.6 a and b).

A long curing cycle to minimise distortion of the bases was used.

After processing, the forms were deflashed, trimmed and fitted
back to the original mounting blocks (see Figure 15.7 e-f). In the
cases of the Zest attachment and the Magnetic attachment, the processing
dummies were removed and replaced with the working attachment using cold
cure on lubricated models both in the fully seated position (see Figure
15.7 d and e).

Wire loops were now constructed which could be mounted in the
Bachmann parallelometer.

One rotating arm of the Bachmann parallelometer was then used to
mount firmly in the vertical position a spring weight gauge1 with
micrometer readings in grams and kilograms. A rotating arm records the
maximum force applied to the object (the breakaway load). The loop was

1. Selby's, Nth Ryde, N.S.W., Aust.
Figure 15.6: Processing the Forms
Figure 15.17: Processed Forms to Fit Individual Mounting Blocks, 
attached to the micrometer gauge firstly from the vertical position and the Bachmann parallelogram arm was lifted by rotation of the gearing handle (Figure 15.8).

Ten successive readings were taken of the breaking load required to separate the components of the jig.

This process was repeated again, instead using the labial lifting arm and again using the lingual lifting arm.

This process was carried out on all six examples. The upper limit of force applied was 3 kgs, as any force above this was obviously excessive and may overload the equipment.

Notation was also made of any tendency for the forms to "lock", which was generally indicated by a wedging tilt of the form and a greater than normal force being needed to separate the attachments.

In one case (the Rothermann attachment) the straight pull exercise was repeated to establish any difference in the primary retention of the attachment before and after the test procedure.

15.3 Results (see Table 5)

The following readings were made and means and standard deviations calculated. Consistent recordings were achieved on all models except when the form "locked" onto the jig, in which case the values increased by at least 1 kg. Significant differences were obvious between different directions of pull. Also in the case of the Rothermann attachment there was a significant difference between the first run of the straight pull and the second run.

Values for the Conod attachment in lingual pull consistently reached 3 kgs at which point no further load was applied.
Figure 15.8: Breakaway Load Recorded by Strain Gauge
### TABLE 5: Values Recorded

#### Plain Root Caps -

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#### Rothermann Attachment -

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### Copod Attachment -

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$\pm 147.2$ $\pm 284$

### Zest Attachment -

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$\pm 54$ $\pm 42.2$ $\pm 81.9$ $\pm 58.1$

### Magnetic Attachment -

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$\pm 8.7$ $\pm 4.6$ $\pm 9.3$
15.4 Discussion

In practice it can be noted that almost any attachment provides adequate retention for an overlay denture when the attachment is first placed and it is correctly aligned and seated. However, there are significant differences which can be noted in the results of these tests, that demonstrate how greatly each type of attachment varies in function. Also, it gives us an insight as to possible cause of tissue damage and failure of attachment copings.

In examination of the results, some factors must be taken into account. Firstly, the study may be limited by the fact that the acrylic mounting blocks, although contoured to simulate the root prominence are nevertheless hard. Tissues of the mouth do exhibit a certain resilience. This is more so on saddle areas than around the crestal bone of roots, and in comparison, acrylic is incompressible. Therefore "locking in" of the models would more easily be demonstrated experimentally. Clinically, this would be a damaging force, traumatic to the labial or lingual gingiva leading to ulceration, inflammatory changes or recession. Tenderness in this area of the mouth would lead to a certain reluctance to adequately clean the area, compounding the injury with the effects of plaque accumulation. The position of the root cap also has significance: if the root was situated in the middle of the bony ridge rather than at the most prominent position, the ridge would have a bracing effect, preventing rotation around the attachment and necessitating a more consistent path of withdrawal.

It can be seen from the results that even the plain root cap exhibits retentive forces (Figures 15.9 and 15.10). This is probably not realistic, but a characteristic of the models and materials used. It is significant, however, that there is an increase in this retention
Figure 15.9: Retentive Readings from a Standard Root Cap
Figure 15.10: A Slight Increase in Retention from a Labial Direction
with the lingual angle of pull. This can be explained as a locking on of the root cap on the vertical lingual surface of the root cap and the labial surface of the root prominence (Figure 15.11).

The exact shape of the root cap has a direct bearing on this effect. A dome shaped root cap, as suggested by many authors previously outlined in the review, would obviously have a significant difference. Factors which may affect plain root cap design may include the anterior placement of the root, the degree of undercut labially and the number of roots being utilised.

In the same manner, attachments which allow the same movement could exhibit the same characteristics. The Rothermann (Figure 15.12), displaying a straight path of withdrawal, provides retention of 466gms. However, by varying the path of withdrawal over 2 kg of force is required to dislodge the attachment. On retesting the straight pull there was a significant drop in retention after only 20 withdrawals, suggesting distortion of the arms of the attachment, rather than wear. It is not surprising that this kind of dramatic increase in retentive force could, in some cases, cause the overloading of the post system.

Post retention has been studied by a number of authors (Table 3) and the table shows that post retention increases rapidly with length. Obviously a short rod and a tapered post should not be used for precision attachment cases of the Rothermann kind, if torquing forces can be applied to the abutment. If, however, the abutment is bounded by other teeth or has resistance to tortion in removal, it may be acceptable.

The Gerber Attachment (Figure 15.13) demonstrated less retention diversity than the Rothermann and surprisingly a drop of retention in the labial pull. Still the lingual path of withdrawal causes a
Figure 15.11: A Significant Increase in Retention when the Form was Lifted from the Lingual
Figure 15.12: Dislodgement Forces with the Rothermann Attachment.
Figure 15.13: Dislodgement Forces with the Gerber Attachment
significant rise in retention. The Gerber probably owes its remove-
ability to its resilient nature, which allows lifting away from the root
face and slight rotation, thus being able to come out of a slight
undercut. This result can probably be extrapolated to other resilient
stud designs, e.g. the Dalla Bona Anchor.

The Conod Anchor (Figure 15.14) is a rigid attachment that is
also tooth supported. In this case it means rigid contact with the
model and no resilient movement. The path of insertion occurs only in
one direction. Therefore, any deviation from the straight pull should
prevent removal of the appliance. Therefore, in the case of a long
abutment or two abutments where a fulcrum line occurs, the rigid type of
attachment not only causes torque on the roots during function (Thayer
and Caputo, 1977) but will also exert excessive force on the abutments
during removal, if the appliance is removed in any other direction than
absolutely vertically.

The Zest Anchor (Figure 15.15) is significant in that a change in
the direction of removal causes very slight variance in the amount of
force required to remove the prosthesis. This could be explained by the
fact that the Zest attachment is flexible, i.e. it will bend to suit the
path of insertion and will not "lock in". The other factor is that the
preparation of the root face is such that there is little in the way of
vertical tooth surface above gingival level. The preparation of the
root face is made low for this very reason.

The matrix, which is inserted into the root, stays low and may
even be counter sunk. This may explain why the post length of the Zest
can be so short. The force required to separate the two components
never exceeds the limit of retention provided by the post. This is
especially true for the Mini Zest. Significantly, on a second run after
Figure 15.14: Dislodgement Forces with the Conod Attachment
Figure 15.15: Dislodgement Forces with the Zest Attachment
Figure 15.16: Dislodgement Forces Using a Magnetic Attachment
eccentric pulls, the Zest attachment showed only slight loss of retentive force in the straight pull.

The Magnetic Attachment (Figure 15.16) demonstrated what appears to be a significantly lower retentive force than the other attachments. In comparison to the root cap example, this can be explained by the concept of "locking on", which occurs on the vertical faces of the root cap. Retentive force of approx. 300gms seems consistent with results by Gillings (1987) on split pole magnets. There would certainly be no increase in retention due to the shape of the keeper, which prevents any "locking on" of the prosthesis. However, how much retentive force is required when overlay dentures incorporate magnets?

It seems important to have strong retention in precision attachments to make the prosthesis "tight" in the mouth, preventing annoying food lodgement under the denture. Thus breakaway load is important in precision attachment dentures. However, magnets have the unique characteristic of being "sticky" - they return to position after slight dislodgement. Hence a magnet could exert a fraction of the retention of a precision attachment, but still be effective as an aid to denture stability. As observed from Figure 15.16, breakaway load diminishes if the prostheses are withdrawn in other than axial directions. Far from being detrimental, this is a benefit as there cannot be overloading of the keeper or of the tissue labial or lingual to the root when the denture is removed. The reason is due to a halving of the magnetic flux surrounding the keeper when the magnet is lifted eccentrically.

A comparison of the graphs (Figures 15.17, 15.18 and 15.19) demonstrates the variability between attachment retention characteristics. Only two attachments, the Rothermann and Conod attachments, displayed over 1kg of difference between directions of pull.
Figure 15.17: A Comparison of Breakaway Loads of the Attachments in the Vertical Direction
Figure 15.18: A Comparison of Breakaway Loads in the Lingual Direction
Figure 15.19: A Comparison of Breakaway Loads in the Labial Direction
15.5 **Conclusions**

A study examining the breakaway forces required to remove overlay denture forms was carried out to determine the significance of different designs of anchorage systems. The results do not cover all attachments, as it was not possible to achieve this. However, interesting differences are shown to exist between each system in the study and these results could apply to other attachments with the same basic characteristics. These findings may be summarised as:

1. Rigid non-resilient attachments exert more force on the attachment and root before breakaway than resilient attachments.

2. If the shape of the attachment on the root face exhibits short vertical walls this may produce "lock in" (my term), where the best course of action for the patient is to reseat the denture and remove the prosthesis from the correct path of withdrawal or risk dislodging the root cap or distorting the arms of the attachment.

3. The lower the root face the less likely there is to be pressure on the labial or lingual tissue.

4. Tissue pressure around the root eminence must occur during removal on any attachment or prosthesis design which allows rotation and which demonstrates an increase in breakaway force with a change in positioning.

5. The magnetic attachment demonstrates the least damaging force on removal of all the designs tested and is possibly the kindest form of retentive fixation to the teeth of the attachments tested in this situation.

It can be seen that one simple factor can dramatically change the prognosis for a case. The design of an attachment is important in
relation to the patient's ability to remove and replace the appliance. The Zest attachment, for example, requires good perception and manual dexterity to insert due to a difficulty in aligning the nylon patrix into the matrix. Gingival damage or permanent deformation of the patrix can occur if the prosthesis is not aligned.

Ball attachments and others allowing rotational movement may allow easier removal and transfer less force to the abutment under loading, but also allow impingement on the labial tissues on removal, which may lead to gingival breakdown on the labial face of the root.

Cylindrical designs only allow one path of insertion and removal, as demonstrated by the Conod attachment, which could not be separated on a lingual pull even when the removal force exceeded 3 kg.

The Rothermann attachment allows some flexibility around its cylindrical patrix. Clinically, however, it is found to be the most likely attachment to "lock in". Withdrawal in an incorrect path causes the inflexible portion of the matrix to be forced over the lip of the attachment, thus requiring greater deflection of the arms, probably exceeding their elastic limit or causing dislodgement of the root cap (Figure 15.20).

It is of interest to note that Dolder (1961) states in most cases of bar joint mandibular dentures, abrasion of the outer edge of the root copings occurred, produced, he deduced, by rotation of the denture about a sagittal or transverse axis which caused intermittent contact and friction between the copings and the base of the denture. This may be associated with the fact that 10% of these patients require amalgam restorations on anterior root surfaces following gingival recession.
Figure 15.20: The Method by Which the Rothermann Attachment can Lock on Withdrawal
CHAPTER 16
OVERALL CONCLUSION

As it can be observed from the content of this study, the forces acting on an overlay denture abutment are complex in nature and dependent on the functional forces of mastication, the position of the overlay denture abutments, and the patient’s own dexterity in removal of the prosthesis. Although it is true that the advantage of overlay dentures is the fact that proprioception is retained, damage to the abutments and their supporting structures can be done, and breakdown can occur, without some patients being aware that their remaining teeth are being damaged. The destructive combination of plaque accumulation and functional overloading can accelerate these remaining teeth to an early demise, whereas a proper and thoughtful design, taking into account all the forces which will apply to a tooth, combined with correct oral hygiene and caries control, can allow these abutments to successfully function and be maintained with better prognosis than free standing teeth.

In a summary of the factors acting on overlay denture abutments, two main forces apply.

1. Axial forces, either towards the tooth or away from the tooth.

   a. **Intrusive Axial Forces** - these forces are the least worry to an overlay abutment as they are the most easily tolerated of the forces for the abutment. Post design to avoid stress concentration may be important to avoid root fracture, however, most root cap designs, including long coping, short dome copings and precision attachment designs, tolerate intrusive axial forces.
b) **Extrusive Axial Forces** - only occur when the root cap design contains a retentive device. Then adequate retentive features must be incorporated in the root cap which will resist the pull of retention device.

The degree of retention depends upon, of course, the type of attachment used.

2. **Rotatory Forces**

Rotatory forces in overlay dentures are, I believe, the most damaging forces to the abutment. These forces can, once again, be divided into intrusive and extrusive forces.

a) **Intrusive Rotatory Forces**

Intrusive forces of the type described by Thayer and Caputo (1980) apply to the abutment teeth under functional loading. One or two isolated abutments obviously are more susceptible to this type of loading. Designs of root caps and attachments each act differently in these situations, but it can generally be noted that non-rotatory designs of attachments cause torquing of the tooth root, whereas as designs that allow rotation of the denture around the root tend to impinge on the supporting structures around the root. Most precision attachments intended for use in overlay dentures incorporate a vertical resilience factor, which is designed to bring the denture into tissue support, rather than complete tooth support under function. The above forces come into play even more, however, as soon as this resilient function is lost due to tissue resorption.

The exception to this problem in retentive attachment designs is magnetic retention, which does not follow the same rules. A magnet is unique from other mechanical devices, in that it offers retention without fixation. Although the abutments are definitely always
functional as supportive components for the denture (i.e. the denture is "tooth supported"), torquing forces do not apply if the root face is flat. Under functional loading of an exterior abutment, pressure is exerted at the distal end of the saddle and on the abutment. Lingual impingement does not occur as there is no possibility of resilient movement of denture over the keeper.

b) **Extrusive Rotational Forces**

As can be seen from my own study of extrusive forces, there appears to be a variance between the forces which are required to cause the breakaway of an attachment in the axial plane and the forces required to cause breakaway in a non axial plane. Once again, attachment designs which allow rotation will cause impingement on the tissues on removal, if they are an isolated abutment, and those attachments not allowing rotation will cause torquing of the abutment. A factor which may minimise this effect on removal of dentures from the mouth may be the incorporation of localising points on the denture base, by which the patient can remove the denture in the most optimal path of withdrawal. However, forces caused by the pull of sticky food will still cause functional rotation in this direction.

The exception to this problem is, once again, magnetic retention, which, because of the nature of magnets, gives less retention in rotatory extrusion due to the fact that maximal retention depends on the flux being distributed evenly over the whole of the magnetic surface. Also, mechanical "locking in" to an undercut is less likely with magnetically retained prostheses.

The retentive requirements for precision attachments reflect the forces to which attachments are applied. It seems practical that exceedingly long posts may not be necessary if the attachments are
allowed to be withdrawn in only one path. Retention required to fix a magnetic keeper seems to be far less than those required for precision attachments and we see far less failure of stainless steel keepers due to loss of retention. It seems that the fracture of roots due to occlusal forces may be of much more significance.

Consequently, the problem of precision attachment use in overlay dentures has been discouraged by several authors, suggesting that abutments should be rounded off and left as simply supports for the denture.

This condition is far less satisfactory to the patient, particularly in the lower denture, as peripheral seal of the denture may not be possible and even though the denture is laterally stable, sticky food lift remains a problem.

Proper design of a case, anticipating the problems that can occur with isolated abutments, and using precision attachments in situations when indirect retention and sufficient abutment support is available, is the desired method to adopt for the success of the overlay denture case.
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