Bridge design, part one: causes of bridge failure

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In the first of a ten-part series, Paul Tipton looks at the evolution of bridge design and examines the reasons for bridge failure.

A recent paper in the *British Dental Journal* (Ibbetson, 1999) highlighted the variations in treatment planning and bridge designs by 55 dentists attending a continuing education course. 70% of respondents chose to reuse abutment teeth which were extensively damaged and had failed to retain the previous bridge. A further 70% chose to use multiple abutments to support the bridgework which, in light of more recent work, appears an outdated concept. How then has bridge design evolved? It is the aim of this paper to discuss the causes of bridge failure.

As long ago as 1926 Ante proposed his law that 'the total periodontal membrane area of abutment teeth should equal or surpass that of the teeth to be replaced'. He postulated that teeth with loss of their supporting structure due to periodontal disease cannot be successfully used as abutments for fixed prosthetic reconstructions. This principle has since been reinforced in the literature (Tylman, 1965; Johnston, 1971; Shillingburg, 1981). However, there is evidence that teeth with very poor periodontal support can serve successfully as fixed bridge abutments in carefully selected cases. Ante proposed his law at a time when periodontal disease and its causes were partly understood and occlusion was based on the concepts of bilateral balance from complete denture prosthetics. Teeth with severe bone loss and marked mobility have been used as bridge and splint abutments (Nyman and Lindhe, 1976). The goal in such cases is not elimination of mobility but rather the stabilisation of the teeth to prevent an increase in mobility (Nyman et al, 1975). In these situations abutment teeth can be maintained free of inflammation, despite their mobility, if certain criteria are met and patients are well motivated and highly proficient in plaque removal. Follow-up studies of these patients with 'terminal dentitions' indicate a low failure rate. Less than 8% of 74 bridges exhibited technical failure in a time span that averaged more than six years (Nyman and Lindhe, 1979). Why, then, do bridges fail?

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Figure 1: Caries around bridge retainers

FIGURE 2: THE CAUSES OF BRIDGE FAILURE

Caries - 37%	Periodontal Disease - 7%
Uncemented crowns - 12 %	Occlusal trauma - 3%
Defective margins - 11%	Mobility - 1.5%
Wear - 7.5%	

Figure 3: Bridge failure due to cementation failure

CAUSES OF BRIDGE FAILURE

Morrant (1956) reviewed bridges made at the Eastman Dental Hospital over a two-year period. He found that most bridges failed because of loss of mechanical retention long before periodontal problems arose. He also noted that the greatest failure rate was with bridges of a fixed-fixed design. Roberts (1970) reviewed 1046 bridges constructed by staff and students at the Eastman Dental Hospital between 1952 and 1964.

He found the greatest failure rate was due to caries (Figure 1) and not periodontal deterioration, due to overloading of

Figure 4 (top left): Crown margins kept supra-gingival with open embrasions for cleaning

Figure 5 (top right): As many as 15% of abutment teeth require endodontics, as opposed to 3% of non-abutment teeth

Figure 6 (bottom left): Caries under bridgework could be partly due to a failure of cementation

Figure 7 (bottom right): Cementation techniques: sustained biting on an orange stick with incorporation of ultrasonic vibration

abutment teeth. Schwartz (1970) examined the causes and frequency of bridge failure and their life span in 406 patients over a three-year period (Figure 2).

Schwartz concluded that the risk of caries and cementation failure (Figure 3) from the incorporation of additional abutments was greater than the risk of occlusal overload from a reduction in the number of abutments in a bridge.

Nyman and Lindhe (1979) studied the failure rates of 74 bridges constructed on severely reduced dentitions both in terms of abutment numbers and periodontal support. The failures were due to loss of retention of retainer crowns from abutment teeth with 3.3%, fracture of abutment teeth at 2.4%, and fracture of bridge components at 2.1%. Bergenholtz and Nyman (1984) reported that as many as 15% of abutment teeth require endodontics. Therefore, it appears that the greatest risk of failure in bridgework is from caries, pulpal pathology, cementation failure and margin design rather than overloading of abutments. These factors will now be discussed in greater detail.

CARIES

It has been previously shown that the highest incidence of bridge failure can be attributed to caries, most frequently the result of poor plaque control, incorrect diet or lack of oral hygiene measures. The Scandinavian studies have shown that their excellent long-term success rates can be partly attributed to a regular maintenance programme and partly to the design of the restorations, which allowed the patient to remove all supra-gingival plaque. All crown margins are kept supra-gingival whenever possible and the width of the inter-proximal areas is adjusted to the size of the instrument used for inter-proximal tooth cleaning (Nyman et al, 1975) (Figure 4). The supra-gingival location of the crown margins facilitated the inspection of the marginal fit of retainers and the early discovery of incipient carious lesions (Nyman and Lindhe, 1979). Christensen (1966) showed the difficulties in assessing marginal fit, and found that practitioners accepted a three times greater marginal deficiency with sub-gingival margins due to their inability to probe and view the margin. Loe (1968) found that sub-gingival margins were related to gingival inflammation and Silness (1970) concluded that margins for cast restorations should be placed supra-gingival wherever possible. The conclusion is that - for longevity - all bridge abutments should have their margins placed supra-gingivally wherever possible. Where there is a lack of retention due to insufficient crown height, periodontal surgery should be performed to increase crown length rather than placing the margins below the gingivae.

PULPAL PATHOLOGY

Most authors concur that the most frequent cause of failure of conventional bridgework is recurrent caries, followed closely by endodontic problems. Bergenholtz and Nyman (1984) reported that as many as 15% of abutment teeth require endodontics, compared to 3% of non-abutment teeth (Figure 5). A review of the endodontic literature by Goodacre and Spolnik (1994) disclosed that between 3% to 23% of teeth prepared for crowns and bridges require endodontic treatment. Those review samples that included predominantly metal and metal-resin prostheses generally demonstrated

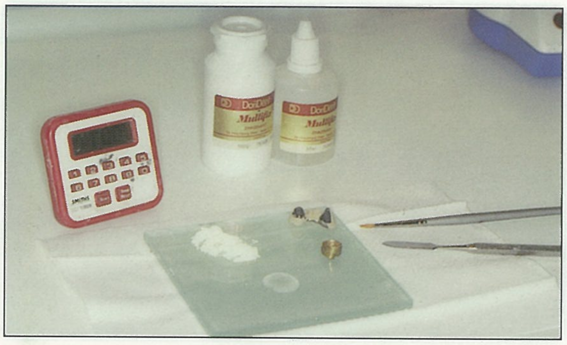

Figure 8: The frozen slab technique

Figure 9: Fixed-movable designs take the stress off the cement lute

fewer endodontic problems than those of metal-ceramic prostheses. The greater tooth reduction for metal-ceramic preparations was the most likely cause.

CEMENTATION

Caries under bridgework could also be partly due to a failure of cementation. This is often seen as air escaping from under margins during seating/unseating forces (Figure 6). It is more difficult to achieve optimum seating of a long span casting, incorporating many abutment retainers, than it is of short-spans. The problem is compounded where periodontally compromised teeth are involved because these teeth will move when a cementation force is placed on them. For these reasons great attention is paid to cementation techniques including when necessary, ultrasonic vibration (Koyano, 1978) or sustained biting on an orange stick (Figure 7). Zinc phosphate is still in the eyes of many people the cement of choice mainly because of its low film thickness, compressive strength and predictability (Pameijer, 1985). For optimum working times it is essential to cool both the mixing slab and the restoration and keep the powder and liquid in the fridge prior to cementation in the mouth or to use the frozen slab technique (Newman, 1980) (Figure 8).

Bridge designs using fixed-movable connectors can help to ease the cementation problem by allowing it to take place in small units, using different cement mixes when required. During functional loading the fixed-movable connector helps takes the stress away from the cement lute (Figure 9). Fixed-movable bridges will be discussed in detail in the next article in the series.

All bridges, both long and short-spans will flex to some extent under biting loads (Shillingburg, 1981). Because these forces are applied through the pontics to the abutment teeth, the forces on castings serving as bridge retainers are different in magnitude and direction from those applied to single restorations. Flexing varies directly with the cube of the length of the bridge and inversely with the cube of its thickness (Figures 10 and 11). For example, if all other factors are unchanged a bridge with a two pontic span will bend eight times as much as a bridge with a single tooth pontic. Making the pontic half as thick will also make it bend eight times as much (Shillingburg, 1981). It is obvious then that when contemplating longer span bridgework the castings should be made thicker in order to reduce this flexing, which in turn would place greater strain on the cement lutes of the restorations. Fixed-fixed designs will be discussed in greater detail later in the series.

The incorporation of double abutments into bridge design when following 'Ante's Law' can place the secondary abutments in tension when the pontics flex, causing the primary abutments to act as a fulcrum. This led Schwartz (1970) to conclude that 'the risk of failure due to caries or cementation failure when additional abutments were incorporated into the bridgework was greater than the risk of occlusal overload from a reduction in the number of abutments'.

MARGIN DESIGN

Gavelis (1981) looked at the type of margin used in cast restorations. He found that the best seat, and therefore least marginal discrepancy, was with a 90° shoulder. This is still the margin of choice for the most aesthetic porcelain shoulder, but needs careful finishing to allow good seat and seal. This design however was the worst at sealing the margin but with the addition of a 45° bevel the sealing effect was increased although this may be more theoretical than practical (Ostlund, 1985) because of the finite thickness of the cement lute. However, this type of margin design may be unaesthetic in certain areas of the mouth (Figure 12). Sozio and Riley (1977) stated that the only material which can cover the bevel is metal, otherwise an overcontoured crown is produced or the porcelain is unsupported and in thin sections at the margin. Aesthetics can be improved for this metal margin by placing it into the gingival sulcus or if supra-gingival by using a gold plating pen (Figure 13) to colour the margin a soft yellow colour, rendering it more aesthetically pleasing to the viewer. Very often there is an orange hue to the tooth at the gingival margin as it emerges from the soft tissue and gold plating the metal margin makes it similar in appearance (Figure 14). Alternatively a yellow bond

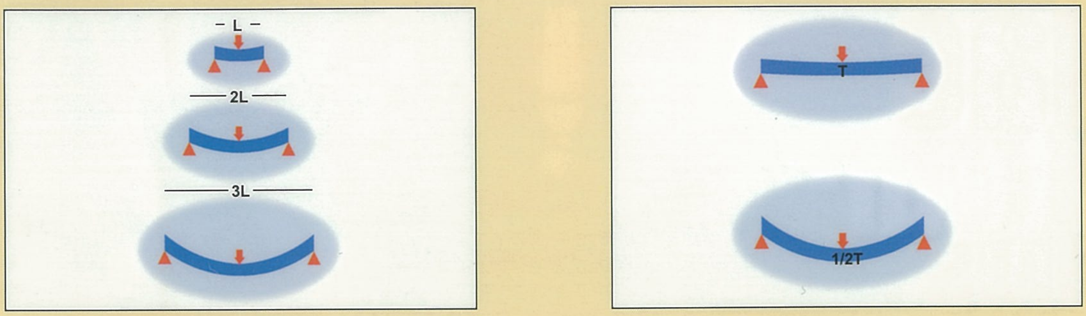

Figure 10 and 11: Flexing varies directly with the cube of the length of the bridge and inversely with the cube of its thickness

ing alloy such as 'Duceragold' can be used. Crispin and Watson (1981) put aesthetics into greater perspective when reviewing the position of crown margins in relation to the lip line. They found that 50% of upper and only 20% of lower central incisor gingival margins are shown in a normal smile. In a follow up study patients were then asked whether they preferred the better tissue health of supra-gingival margins or the greater aesthetics of sub-gingival margins and 64% chose health and a supra-gingival margin (Crispin and Watson, 1981) over better aesthetics. Shillingburgh (1981) has also shown that the shoulder bevel margin is the best at overcoming porcelain shrinkage which can distort the metal framework, especially the longer span bridges (Figure 15).

The shoulder bevel margin can be used with several marginal angles: 30° and 60°. Whilst the 45° bevel on the shoulder is the standard preparation for the porcelain fused to metal labial or buccal margin in non or semi-aesthetic areas the alternatives are commonly used.

The 30° bevel - known also as the short bevel - gives the restoration a metal finish line making the margin slightly more aesthetic. It can thus be used in semi-aesthetic areas by placing the shoulder at the gum margin and placing the bevel just onto the sulcus. It is also the preparation of choice where a bevel is required on the shoulder of a mobile or very long tooth and this margin allows better seating than the 45° bevel.

The 60° bevel known also as the long bevel gives the restoration a full metal collar, making the margin less aesthetic. The more the angle of the bevel parallels the axial taper the more retentive the preparation becomes. This margin is therefore the one of choice when preparing for a post crown as a good ferrule is required without too much tooth reduction.

OPPOSING DENTITIONS

Schwartz et al (1970) concluded that the best opposing dentition for bridgework was a full denture whilst the worst was a partial denture because of the increased chances of failure this brings from caries and periodontal disease. Lundgren (1991) has shown however, that for distal extension cantilever bridges, the full upper denture opposing the lower bridge is the worst prognosis because anterior ridge resorption ('Combination Syndrome') causes posterior tilting of the denture during chewing, increasing the forces on the distal cantilever pontics. Cantilever bridges will be discussed in more detail later in the series.

CONCLUSIONS

Many texts have been written about bridge design from the point of view of reducing the failure rate from overloading by over emphasising Ante's Law. A review of the literature on bridge failure shows that most fail due to caries, pulpal pathology, cementation failure or margin breakdown and not by overloading. Schwartz concluded that most failures occur around and because of teeth. The added risk of incorporating more than one retainer at the end of a bridge outweighs the theoretical risk of bridge overloading which appears to be a very small cause of failure.

The next article in this series will concentrate on fixed-movable bridgework. ■

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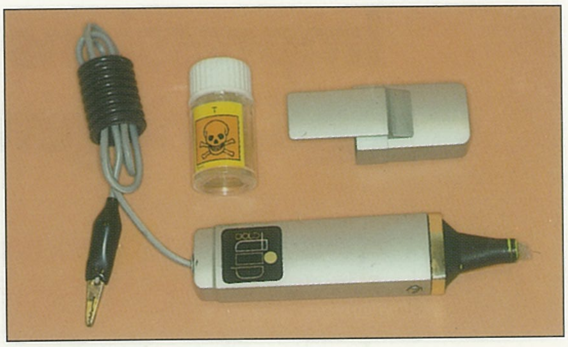

Figure 12 (top left): The 45° bevel type of margin design may be unaesthetic in certain areas of the mouth because of metal showing

Figure 13 (top right): A gold plating pen

Figure 14 (bottom left): Improved supra-gingival aesthetics on the molar restrainer achieved by gold plating the margin

Figure 15 (bottom right): the shoulder bevel margin is best at overcoming porcelain shrinkage which can distort metal framework, espcially in longer span bridges

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