PROSTHODONTIC MAINTENANCE OF IMPLANT-SUPPORTED PROSTHESES

CHRISTOPHER SMITH

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Faculty of Dentistry, University of Sydney
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Statement of Authorship

I declare that all the work presented in this treatise is my own, unless otherwise stated. The work of colleagues is acknowledged in general terms within the acknowledgements and specifically within the body of the text, wherever it is appropriate.

Christopher Smith

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INTRODUCTION

A successful dental prosthesis remains in long-term service, optimizing masticatory function and comfort, and enhancing facial appearance. Prosthodontic management of the edentulous patient with conventional complete dentures may provide acceptable facial appearance, but fails to provide adequate function and comfort for a significant group of denture wearers. The term maladaptive has been used to describe those people who have difficulty adjusting to dentures. The maladaptive group can be subdivided into three subgroups. Class I are those who are able to adapt to dentures physically but not emotionally. Classes 2 are those who are unable to adapt either physically or emotionally. Class 3 are those who cannot wear dentures and as a result isolate themselves from society and become chronically depressed (Davis, 1998). Clinical considerations that singularly or collectively preclude comfortable wear of a complete denture for the Class 2 and 3 maladaptive patients include severe morphologic compromise of the denture bearing area accompanied by a non-retentive prosthesis, parafunctional oral activity associated with recurrent soreness of supporting tissues and lack of denture stability, an apparent lack of oromuscular co-ordination, a hyperactive gag reflex elicited by the removable prosthesis and the patients inability to adapt to wearing dentures (Zarb and Schmitt, 1990).

The osseointegration technique introduced by Branemark and colleagues catalyzed a paradigm shift in the management of the edentulous patient (Adell *et al.*, 1981). The installation of commercially pure titanium implants of a defined finish and geometry created a firm, intimate and lasting connection between the fixture and host bone. Bone anchorage of osseointegrated implants, could now provide a stable supporting mechanism for prosthetic restorations. The prosthesis may be supported entirely by dental implants such as complete/partial fixed bridgework and single tooth restorations, or share the support with the oral mucosa, as with overdentures with short bar or ball attachments. The psychological reactions to tissue-integrated prostheses have been reported to be most gratifying, with an improved quality of life and regained self-confidence (Davis,1998; Lundqvist and Carlsson 1983; Albrektsson *et al.*, 1980).

Despite the success of osseointegration, recent studies have revealed significant post-insertion complications and maintenance requirements of implant supported prostheses (ISP).

Selected Studies

This review is based upon 19 recent studies reporting maintenance requirements of ISPs.

A. Patient number, sex distribution and mean age of samples investigated. (Table 1.)

Studies show a large variation in sample size, and only 5 studies having a sample greater than 100 subjects. The mean age of the study population in these studies was 54.5 years. A greater proportion of females to males (1.6:1) existed in the study population, and this may relate to the greater utlization by females of health care facilities. Regardless of the gender distribution within the studies, almost no differences were noticed between men and women regarding frequencies of adjustments and complications (Adell *et al.*, 1990;den Dunnen *et al.*, 1997; Carlson and Carlsson, 1994).

Table 1.

Investigators	Sample size	Male	Female	Mean Age
Zarb,Schmitt 1990	46	10	36	-
Jemt,Lekholm,Grondahl 1990	16	8	8	-
Johansson,Palmqvist 1990	47	22	25	-
Jemt 1991	384	169	215	-
Naert,Quirynen,Theuniers,van Steenberghe 1991	86	21	65	56.5
Jemt,Linden,Lekholm 1992	87	42	45	53
Jemt,Book,Linden,Urde 1992	92	29	63	59
Tolman,Laney 1992	353	97	256	55.3
Hemmings,Schmitt,Zarb 1994	50	7	43	54
Jemt 94	76	48	28	60.1
Ekfeldt,Carlsson,Borjesson 1994	77	47	30	-
Walton,MacEntee 1994	156	45	111	-
Carlson,Carlsson 1994	561	241	320	-
Henry,Bower,Wall 1995	15	3	13	50
Allen,Smith,McMillan 1997	60	-	-	-
den Dunnen,Slagter, de Baat,Kalk 1997	104	30	74	53.2
McMillan,Allen,Ismail 1998	58	23	35	43
Naert, Gizani, Vuylsteke, Van Steenberghe 1999	60	17	19	63.7
Kiener, Oetterli, Mericske,Mericske-Stern 2001	41	17	24	61.2

B. **Prostheses** (Table 2)

The most commonly utilized ISP in increasing order:

i. partial bridgework (PB)
ii. single tooth implant crown (ST)
iii. overdenture (OD)
iv. full arch bridgework (FB)

The large number of FB and OD reflect the initial prosthetic application of the osseointegrated technology to the edentulous arch. With the long-term documented stability of osseointegrated fixtures, implant prosthetic restoration was extended to PB and ST replacement.

Table 2.

Studies	**ST**	**PB**	**FB**	**OD - bar**	**OD - ball**	**OD - magnet**
Zarb,Schmitt 1990	-	-	49	-	-	-
Jemt,Lekholm, Grondahl 1990	23	-	-	-	-	-
Johansson,Palmqvist 1990	-	-	49	-	-	-
Jemt 1991	-	-	391	-	-	-
Naert,Quirynen,Theuniers,van Steenberghe 1991	-	-	-	71	-	-
Jemt,Linden,Lekholm 1992	-	127	-	-	-	-
Jemt,Book,Linden, Urde 1992	-	-	-	90	1	1
Tolman,Laney 1992	-	-	250	60	-	-
Hemmings,Schmitt, Zarb 1994	-	-	25	23	-	2
Jemt 94	-	-	76	-	-	-
Ekfeldt,Carlsson, Borjesson 1994	93	-	-	-	-	-
Walton,MacEntee 1994	12	29	79	56	15	-
Carlson, Carlsson	50	75	439	22	14	
Henry,Bower,Wall 1995	-	-	15	-	-	-
Allen,Smith, McMillan 1997	-	9	20	31	6	-
Abram, den Dunnen,Slagter, Cees de Baat,Kalk 1997	-	-	-	104	-	-
McMillan,Allen, Ismail 1998	76	-	-	-	-	-
Naert, Gizani, Vuylsteke, Van Steenberghe 1999				12	12	12
Kiener,Oetterli, Mericske, Mericske-Stern 2001	-	-	-	33	8	

COMPLICATIONS OF OSSEOINTEGRATED IMPLANT PROSTHESIS

The following complications can occur with the placement of implant prostheses: the loss of implant anchorage, soft tissue and mechanical complications.

LOSS OF IMPLANT ANCHORAGE

A. Survival Rates

Implant teams have reported lower survival rates of fixtures placed in the development groups, ranging from 37% - 84 %. The lower rate of fixture survival is attributed to the surgical learning of the implant team (Adell *et al.*, 1981; Zarb and Schmitt, 1990).

Current long-term fixture survival rates have improved to 90% for the maxilla and at least 95% for the mandible, as the surgical and prosthodontic teams develop improved implant clinical skills, and management with bone anchored prostheses becomes routine (Adell *et al.*, 1990; Lekholm *et al.*, 1999; Bahat, 2000). Table 3 lists the fixture failures occurring in the selected studies. The type of fixture placed was essentially that of the Branemark system. Overall, the mean survival of fixtures was 96%.

Table 3.

Investigators	Type of Fixture	Number fixtures placed	Study Period (months)	Fixture Loss
Zarb,Schmitt 1990	Branemark	274	48-118	30
Jemt,Lekholm,Grondahl 1990	Branemark	23	36	2
Johansson,Palmqvist 1990	Branemark	286	36-118	25
Jemt 1991	Branemark	2199	12	36
Naert,Quirynen,Theuniers,van Steenberghe 1991	Branemark	196	4- 48	1
Jemt,Linden,Lekholm 1992	Branemark	354	12	5
Jemt,Book,Linden,Urde 1992	Branemark	430	42	69
Tolman,Laney 1992	Branemark	1178	1-75	59
Hemmings,Schmitt,Zarb 1994	Branemark	200	60	18
Jemt 94	Branemark	449	60	31
Ekfeldt,Carlsson,Borjesson 1994	Branemark	94	14-55	2
Walton,MacEntee 1994	Branemark	781	2-78	-
Henry,Bower,Wall 1995	Branemark	83	120	0
Allen,Smith,McMillan 1997	Branemark	236	<12-36	4
Abram, den Dunnen,Slagter, Cees de Baat,Kalk 1997	IMZ/Branemark	204/4	36	1
McMillan,Allen,Ismail 1998	Branemark/Calcitek/Astra	68/6/2	8-83	3
Naert, Gizani, Vuylsteke, Van Steenberghe 1999	Branemark	72	60	1
Kiener,Oetterli,Mericske, Mericske-Stern 2001	ITI	173	12 - >60	8

B. Aetiology of Fixture Failure

Fixture failure may be due to a failure to achieve osseointegration (early failure) or the failure to maintain osseointegration (late failure) (Esposito *et al.*, 1999).

i. Early fixture failure may be due to;

- Surgical trauma - Lack of operator surgical experience or thermal trauma (>47 C for 1 minute).

- Impaired healing ability - Such as diabetes, irradiation of jaws, or cigarette smoking. The reported fixture failure rate for non-smokers varies between 2 - 4.76 % and for smokers 9 - 11.76% (Bain and Moy, 1993; De Bruyn and Collaert, 1994).

- Premature loading – It is not the absence of loading per se that is critical for osseointegration, but rather the absence of excessive micromotion at the interface. Excessive micromotion damages tissue and vascular structures, interferes with early scaffold development into fibrin clot and disrupts angiogenesis and promotes healing by repair. The threshold of micromotion beyond which osseointegration will not occur, is suggested to be 100 μm.

- Infection and immunological factors – Failure to use preoperative antibiotics; bacterial contamination of the implant, and or the wound, in the course of surgery (Esposito *et al.*,1999).

- Anatomic conditions – Poor bone quantity and quality. Implant failure rate is higher in Type 4 bone (Jaffin and Berman, 1991).

ii. Late implant failures have been attributed to;

- Local and systemic factors related to host health, which alter bone metabolism and influence the remodeling capacity of bone.

- Biomechanical overload – Dental implants lack a supportive and proprioceptive periodontal ligament, which leads to a reduced inability to detect heavy occlusal forces and allows force transmission to be applied directly to surrounding bone interface. With functional overload, due to parafunction or poor biomechanical implant or prosthetic design, microfractures may develop in bone around the coronal aspect of the bone- implant interface. When the functional capacity of the bone and or bone-implant interface is exceeded by biomechanical demand, the bone remodeling process is triggered by the accumulation of microcracks, resulting in bone resorption. This loss of bone allows soft tissue invasion into the space between the bone and the implant. If stresses continue to be excessive or bacterial infection is present, bone loss will progresses (Tonnetti and Schmid, 1994).

- Periimplantitis – A plaque induced site-specific infection, with the association of anaerobic bacteria that results in the loss of supporting bone in tissue surrounding a functioning implant. DNA probe analysis indicates the pathogens identified are similar to those found in periodontal disease with moderate levels of A. actinomycetumcomitans, P. intermedia, P. gingivalis. The overall frequency of periimplantitis is 4-15 % (Mombelli and Lang, 1998).

Soft Tissue Complications

Soft tissue complications experienced include the following;

i. **Perimucositis** – Periimplant mucositis is the reversible inflammation of the soft tissues surrounding implants in function (Mombelli and Lang, 1998) . Typical clinical manifestations of gingivitis and mucosal hyperplasia are a response to chronic irritation and poor oral hygiene (Henry *et al.*, 1995; McMillan *et al.*,1998). The incidence of perimucositis has been reported to be between 1% and 32 % (Goodacre *et al* 1999), and a greater propensity for mucosal inflammation and hyperplasia has been reported with ODs, compared with implants supporting a FB (Jemt *et al.*, 1992; Enquist *et al.*, 1988; Naert *et al.*, 1999). Conservative management has included professional prophylaxis of abutments and oral hygiene instructions, to surgical periimplant soft tissue management (den Dunnen *et al.*,1997; Henry *et al.*, 1995). Removal of the prosthetic superstructure may be necessary to provide access for adequate treatment.

ii. **Fistulae** - The incidence of fistulae associated with osseointegrated implants is reported between < 1% to 25% (Goodacre *et al.*,1999). Management of fistulae occurring at the implant-abutment level has involved retightening of abutment screws, following the cleaning of prosthetic components (Ekfeldt et al., 1994; Jemt, 1991).

iii. **Deep peri-implant sulci or mobile mucosa** - Is a common reason to perform periodontal surgery (Johansson and Palmqvist., 1990).

iv. **Decubitus ulcers** - Are found close to the periphery of the prostheses, and reported within one month after insertion or relining of an OD (Naert *et al.*, 1999). Complete upper dentures opposing an ISP are subjected to higher loads, dislodge more easily, and produce resultant soft tissue trauma (den Dunnen *et al.*, 1997; Jemt *et al* 1992). Adjustment of the fitting surface of the denture to minimize pressure to areas of soft tissue inflammation and ulceration, together with occlusal adjustment, is a common maintenance procedure with OD (Kiener *et al.*, 2001; Watson and Davis, 1996)

Mechanical complications

For the prosthodontist the most time-consuming and often perplexing complications to manage are those precipitated by mechanical factors. Complications may arise from inappropriate superstructure design, ill-fitting framework, mechanical or component incompatibility, or occlusal scheme and masticatory function disharmony.

Biomechanical considerations of ISP (Taylor *et al.*, 2000)

i. **Axial Loading** - There is no scientific evidence that the osseointegrated interface responds differently to compressive forces than it does to tensile or shear forces of similar magnitude. Experimental evidence does not substantiate the concern regarding non-axial loading. A recent clinical study of implants placed in tilted positions in the maxilla indicated a cumulative success rate of 98% after 5 years (Krekmanov *et al.*, 2000). When the issue of non-axial loading is extended to include the restorative components of dental implants, the concern may well be justified. Screw-retained components of implant systems are less able to withstand non-axial forces than those within the long axis of the pillar. This is related to the mechanics of the screw joint. Axial forces maintain the apposition of implant components and augment the joint clamping forces. Non-axial loading, leads to the development of joint separating forces, which can lead to the failure of the screw joint. Non-axial loading can lead to plastic deformation, wear, or fatigue failures of implant restorative components (McGlumphy *et al.*, 1998).

ii. **Cantilevers** - The literature on the use of cantilevers in ISPs is largely anecdotal, and evidence from clinical data is lacking. Many authors have given their recommendations for when a cantilever prosthesis is permissible, and how many implants are necessary to support a cantilever. Empirical recommendations for length of cantilever are given as a function of implant position (A-P spread), arch form and length, cantilever location (maxilla or mandible), and opposing occlusion. The recommendations are successful when followed, but the evidence to support them is missing.

iii. **Tripodization** – The use of tripodized implant placement in the posterior quadrant is a concept that makes geometric sense, but has not been demonstrated clinically to be superior to a conventional design utilizing 2 implants and a 3 or 4 unit PB.

iv. **Occlusal scheme** - Occlusal anatomy has been described many times empirically, but has not been examined scientifically. For a ST, the torque is a product of the force and the perpendicular distance from the area of maximum fixture loading. Methods of occlusal alteration to reduce torque on implants, by bringing the resultant line of force closer to the implant and supporting bone include (Weinberg, 1998) ;

- Avoidance of excursive contacts, by reduction of cusp inclination.

- Avoidance of off-axis centric contacts with posterior occlusal contact eliminated from cusp tips and marginal ridges, and the centric contacts placed close to the screw access hole. Modification of the occlusal scheme to a crossbite when maxillary implants have an exaggerated lingual offset, and concomitant reduction of the mandibular lingual cuspal inclination.

- Modification of posterior occlusal anatomy to provide true cusp-fossa occlusal relationships. It is suggested that occlusal line angles and grooves be reshaped to contain a 1.5mm horizontal fossa.

- Modification of the anatomy of the maxillary anteriors to produce horizontal palatal stops for the mandibular incisor.

v. **Passive Fit**

Passive fit is defined as a state in which there is no gap between the bearing surface of a fastened superstructure and its abutments in the absence of unfavorable strain (Patterson, 1995).

There is a theoretical consensus on the importance of passive fit between the dental implant components and the superstructure framework. The rationale is based on the fact that osseointegrated implants have no resilience in the bone, and so cannot adapt to a misfitting framework without generating tension in the bone as well as in the metal framework. (Cox and Zarb, 1987; Watanabe *et al.*, 2000; Jemt and Book 1996).

Problems related to poor fit of frameworks connected to implants have been discussed in association with excessive marginal bone loss and failure of implants (Adell *et al.*, 1981), as well as in relation to mechanical problems of screw loosening and fatigue fractures of implant components. The lack of passive fit is said to cause microvibrations, which would loosen screws (McGlumphy et al., 1993). Others suggest that the ill-fitting screw retained framework, applies separating forces to the screw joint, as it attempts to return to its original position (McGlumphy *et al.*,1998).The influence on bone response by prosthesis fit has not been demonstrated in invivo studies.

Empirical guidelines for acceptability of prosthesis fit include ;

- Passive fit should exist at the 10um level (Branemark,1983).
- Castings with discrepancies greater than 30 μm over more than 10% of the circumference were unacceptable (Klineberg and Murray, 1985)
- A misfit smaller than 150 μm is acceptable (Jemt, 1991; Jemt & Lie, 1995).

The fit of FB has been retrospectively investigated, and none of the prostheses examined were of a passive fit. However, no bone loss was observed around the supporting fixtures, even after 5 years of function. The authors concluded there must be a range of misfit tolerated by implants that still allows long- term fixture stability (Jemt and Book, 1996).

Methods to determine prostheses misfit include (Kan *et al.*, 1999) ;

- Alternate finger pressure – The prosthesis is seated and finger pressure is applied alternatively over the terminal abutments, and observation of fulcruming and or saliva movement at the prosthesis abutment-junction is observed. Any rocking and or saliva movement detected at the framework-abutment interface is considered a misfit.

- Direct vision and tactile sensation - With an explorer, and assisted by magnification. Sensitivity of this test is limited by the size of the explorer tip (60um), location of the margin (subgingival margins), and the clinician's discriminative ability.

- Radiographs – Including long cone periapical radiographs. Anatomic limitations may prevent proper alignment of the radiograph, resulting in overlapping of components that may mask prostheses misfit.

- One-screw test - A terminal abutment screw is tightened, and discrepancies are observed at the opposite terminal abutment. This method is combined with direct vision and an explorer for assessment of supragingival margins, and with periapical radiographs for subgingival margin assessment.

- Screw resistance test – Gold screws are tightened one by one, starting with the implant closest the midline. When initial resistance of the gold screw is encountered, a maximum of one half turn is allowed to completely seat the screw, and achieve a torque of 10-15 Ncm. A misfit is considered when more than half a turn is needed to achieve the desired screw seating and torque measurement.

- Disclosing media – The use of disclosing wax or a pressure-indicating paste, which is applied to the seating surface of the prosthesis. The presence of disclosing media at mating surfaces for the framework indicates misfit. This test can be applied to both supragingival and subgingival margins.

Solutions offered to achieve a passive fit ;

- Separation and soldering for gold alloy superstructures.
- Laser welding of titanium casting alloys.
- Electrical discharge machining
- Cemented restorations.

Table 4 and 5 list complications and maintenance reported in the literature from 19 studies.

Table 4

	Zarb,Schmitt 1990	Jemt,Lekholm Grondahl 1990	Johansson, Palmqvist 1990	Jemt 1991	Naert,Quirynen Theuniers,van Steenberghe 1991	Jemt,Linden Lekholm 1992	Jemt,Book Linden, Urde 1992	Tolman, Laney 1992
Gold screw fracture	53		3					
Gold Screw loose					8	103	1	
Abutment screw fracture	9		3					89
Abutment screw loose		4			2		2	6
Abutment damaged								
Abutment replacement								
Framework ill fitting								
Framework fracture	13		1	3			1	2
Clip fracture								
Clip loosening								
Clip tightening					31		16	
Clip replacement							20	
Magnet-keeper loosening /fracture					7			
Denture tooth fracture			11	18			2	
Denture tooth attrition			3					
Acrylic resin fracture		3	11			5	13	
Porcelain fracture								
Contour modification							12	
Occlusal adjustment				7		7	5	
Opposing prosthesis fracture								
Reline opposing prosthesis								
Reline ISP			5					
Remake opposing prosthesis								
Remake ISP		17		2				
Soft tissue complications		4		63				109
Peri-implant surgery			23			7	18	39
Professional hygiene								
Esthetic	0	9		12		9		
Speech	1			43			4	
TMD	12			8				

Table 5

	Hemmings, Schmitt Zarb 1994	Jemt 94	Ekfeldt, Carlsson, Borjesson 1994	Walton, MacEntee 1994	Henry, Bower Wall 1995	Allen, Smith, MacMillan 1997	den Dunnen, Slagter,Cees de Baat, Kalk 1997	MacMillan, Allen,Ismail 1998	Kiener, Oetterli, Mericske, Mericske-Stern 2001
Gold screw fracture	5			30	2	1	52		
Gold Screw loose	9	4		18		13			15
Abutment screw fracture	11			11	8	8			
Abutment screw loose	5		40			2		2	3
Abutment damaged							6		
Abutment replacement							34		
Framework ill fitting									
Framework fracture	1	1		7					7
Clip fracture	3			4					9
Clip loosening	10			43					
Clip tightening				38			21		2
Clip replacement						7			
Magnet-keeper loosening /fracture	7								
Denture tooth fracture	5	73		30	23	3	12		6
Denture tooth attrition					3				3
Acrylic resin fracture	7		2	24		5			1
Porcelain fracture			1	8		2		2	
Contour modification				119		5	22		16
Occlusal adjustment				44			17		11
Opposing prosthesis fracture						10			
Reline opposing prosthesis	12				3		24		
Reline ISP	8			37	6		10	3	2
Remake opposing prosthesis					7		1		
Remake ISP	14	20	9		6				
Soft tissue complications	38	44			2		41	23	4
Periimplant surgery	7		106				6		
Professional hygiene									
Esthetic							2		
Speech		30		5					
TMD	1	6					2		

Which prostheses require the most maintenance?

Complications occur most often with removable prostheses and least often in single tooth replacements (Carlson *et al.*, 1994).

What are the common maintenance requirements?

A. Single Tooth

With the external hex configuration of the Branemark fixture, the axial preload of the abutment screw is a determining factor for the stability of the implant- abutment connection. The original titanium abutment screws experienced loosening in a high percentage (up to 43%) of single tooth implants, and required tightening more than once in a smaller percentage of cases (Ekfeldt *et al.*, 1994). This problem has been resolved with the fabrication of a gold palladium abutment screw (Scheller *et al.*, 1998). This gold abutment screw has an increased stem length that aids in attaining optimal elongation, and short thread lengths that reduce friction. The gold alloy also has a lower coefficient of friction and is not subject to galling. The titanium screws developed galling, and this limited their preload. The yield strength of the gold abutment screw is 1270- 1380 N, and it can attain a preload more than twice that attainable with a Ti screw. The higher preload results in stable screw joint and a greater the resistance to screw loosening (Binon, 2000; Tan and Nicholls 2001). Loosening of abutment screws with the Cera-One abutment is reported as infrequent (1-6%) (Scheller *et al.*,1998). This was attributed to the use of the gold abutment screw and the use of a machine torque to secure the screw at 32Ncm.

There is a low prevalence of crown de-cementation of ST units, even in cases where provisional cements are used. This is most likely due to the parallelism of the abutments and the close fit of the crown to the abutment (McMillan *et al.*, 1998).

Remake of permanently cemented ST was necessary when associated with loose abutment screws, crown fracture, or incorrect cementation resulting in a failure to completely seat the crown on the abutment (Ekfeldt *et al.*, 1994; Jemt *et al.*, 1990). Crown fracture has been reported in a 5 – year multi-center study at 11%, and involved all ceramic crowns (Scheller *et al.*, 1998).

B. Overdentures

Maintenance of overdenture prostheses include;

1. Bar clips - Clip activation of overdentures may be necessary for 50% of prostheses (Watson *et al.*, 1997), and is required with increasing incidence over time (Jemt *et al.*, 1992; Naert *et al.*, 1991; Naert *et al.*, 1999). There is a high rate of clip fracture of 19 - 33% (Watson *et al.*, 1997; den Dunnen *et al.*, 1997; Jemt *et al.*, 1992; Walton and McEntee, 1994; Kiener *et al.*, 2001; Allen *et al.*, 1997). Clip replacement was the most frequent requirement for repeated repair for overdentures (den Dunnen *et al.*, 1997).

2. Bar fracture – Fracture of OD bars is very uncommon and may be attributable to inadequate soldering or casting-on at the junction between the gold cylinder and bar (Watson *et al.*, 1997).

3. Magnets - Corrosion, rapid loss of retention, loosening or fracture of magnetic keepers and extreme wear are the main reasons for the discontinued use of magnets. (Davis *et al* 1996; Naert *et al.*, 1991; Hemmings *et al.*, 1994; Naert *et al.*, 1999).

4. Ball attachments – Frequent tightening of abutment screws, renewal of O-rings and O- ring boxes is required. (Davis *et al.*, 1996; Naert *et al.*, 1991; Naert *et al.*, 1999).

5. Prosthetic screws - Tightening was prevalent for abutment (18%) and gold screws (15%) (Watson and Davis, 1996; Naert *et al.*, 1991; Kiener *et al.*, 2001).

6. Acrylic resin – Is the most common prosthodontic complication, and includes wear, fracture and or aesthetic defects of acrylic resin (Watson & Davis 1996; Carlson *et al.*, 1994; Watson *et al.*, 1997). Resin fractures increased with time, suggesting a fatigue pattern (Jemt, 1994). Where a cast metal framework is utilized (Kiener *et al.*, 2001) or in the absence of direct contact between the denture base and implants (den Dunnen *et al.*, 1997), no acrylic resin fractures were reported.

7. Relines – It has been noted that a relatively high number of relines were required in conjunction with the placement or post-placement care of implant OD and the frequency of relines required during follow-up of implant supported OD varies from 6.5 – 44 % (Goodacre *et al.*, 1999; Watson *et al.*, 1997).

C. Fixed Bridges

Fractured screw components are often discovered incidentally, either at routine follow-up, prosthesis removal, or at times outside the follow-up protocol, when the bridge was electively removed because the patient presented with the complaint of altered sensation on biting (Henry *et al.*, 1995). The incidence of abutment and gold screw fracture is reported at 0.5% - 8% (Goodacre *et al*, 1999; Adell *et al.*, 1981 ; Hemmings et al., 1994). The most common feature is fracture of the hexagonal head from the main body of the abutment screw (Zarb and Schmitt, 1990). SEM of the fractured components revealed that all fractures were consistent with stress fatigue (Henry et al., 1995).

The gold screw fractures because they are designed to be the weakest link in the "hardware" chain, and their repair is less complicated than lower components or loss of osseointegration. Cyclical stress loading may lead to loosening of prosthetic screws or screw fracture. It could be argued that the occasional fracture of the prosthetic screws and their relatively easy replacement emphasizes the built-in safety and retrievability features of the Branemark system (Zarb & Schmitt 1990; Naert *et al.*, 1991).

An increase in gold screw loosening in PB compared to FB has been reported. This may be the result of unfavorable distribution of forces placed on fewer implants in a relatively straight line in the partially edentulous situation, and the presence of higher occlusal forces encountered in the posterior region of the mouth.

Repeated tooth fracture, may be related to inadequate support from the design characteristics of the original framework (Henry *et al.*, 1995). A high percentage of fractures of the acrylic resin superstructure and or artificial teeth, together with extensive attrition, have been reported (Carlson and Carlsson, 1994; Watt and Zarb, 1998 ; Jemt, 1994). This could be due to laboratory techniques, bruxism, or a combination of the two (Henry *et al.*, 1995; Johansson and Palmqvist, 1990).

Repair of the superstructure is a common procedure, whereas a new superstructure or a totally new prosthesis was an infrequent requirement (Johansson and Palmqvist, 1990).

Where the opposing dentures were loose or fractured, in 10-30 % of patients following issue of mandibular ISP, a reline or remake of the opposing denture was required (McMillan *et al.*, 1998; Naert *et al.*, 1991; Hemmings *et al.*, 1994; Walton and MacEntee, 1994). Other investigators have found no increased need for relines, nor was there occurrence of midline fractures of maxillary dentures opposing a mandibular ISP (Zarb and Schmitt, 1990).

Framework fractures have been reported in the cantilevered portion of FB. This may be related to the use of an inferior casting alloy, such as silver palladium alloy, with a reduced yield and tensile strength, inadequate metal thickness, excessive cantilever length, poor solder joints, parafunctional habits, and improper framework design (Albrektsson, 1988; Zarb and Schmitt, 1990).

How many appointments?

Most patients (75.5%-82.6%) required less than 4 appointments in the first year (Jemt, 1992; Jemt, 1991; Kiener *et al.*, 2001), with a high percentage requiring only a single appointment (McMillan *et al.*, 1998; Allen *et al.*, 1997). A small percentage (9%) required more than 10 appointments in the first year, and accounted for a large number of complications (Zarb and Schmitt., 1990; Jemt., 1994).

Over a 5-year period, the mean number of visits for maintenance of a FB and an OD, has been reported to be 9 and 15 visits respectively (Watson and Davis, 1996).

How much time is spent?

The average time needed for prosthodontic maintenance was 0.64 hours per unit / year. This figure was higher for maxillary compared with mandibular units. It does not include time spent on recall appointments or oral hygiene care (Johansson and Palmqvist, 1990).

The clinical time necessary for adjustment of complications averaged 1hour for OD and FB, and a little more than ½ hour for PB and ST replacements (Carlson *et al.*, 1994)

From the patient's perspective, the fact an appointment would last 10 minutes or 1 hour is secondary to the inconvenience of having to make the journey to and from the clinician for treatment.

When do complications occur?

An adjustment was usually carried out in the first year post-insertion (Hemmings *et al.*, 1994; Allen *et al.*, 1997). At least 70% of repairs for both FB and ODs were needed within the first year after insertion (Walton and MacEntee, 1994; Allen *et al.*, 1997). OD were found to require more adjustments that FB within the first year post-insertion (Hemmings *et al.*, 1994).

Conflicting evidence has been presented for the maintenance requirements after the first year. Similar maintenance requirements for FB and OD have been reported following the first year of issue (McMillan *et al.*, 1998; Allen *et al.*, 1997). Other investigators report a greater maintenance requirement for fixed prostheses after the first year of service (Hemmings *et al.*, 1994).

If this pattern of higher maintenance requirements for an OD exists for a period of 5-10 years, it could be questioned whether on economic grounds, there is justification for choosing an OD , when adequate bone is available bone to support a fixed prosthesis.

CONCLUSION

ISPs incorporate numerous components, which may require some form of maintenance. The key issues regarding maintenance include –

1. Maintenance requirements for ISP are significant and patients should be advised of this.
2. Most repairs and adjustments to ISP occur within the first year of service.
3. Maintenance requirements may be higher for removable than fixed implant supported prostheses.
4. It is important to have information on the complication and maintenance requirements associated with ISPs, in order to predict the long-term cost implications.
5. The osseointegration team has a lifelong responsibility for follow-up and maintenance.

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PROSTHODONTIC MAINTENANCE OF IMPLANT-SUPPORTED PROSTHESES : retrospective analysis.

Christopher Smith
MDSc Prosthodontics

MAINTENANCE OF IMPLANT SUPPORTED PROSTHESIS

Study Group - Total of 464 patients.

Lost to followup - A total of 97 (20.1%) patients were lost to follow-up due to;

- 87 patient files could not be traced because of a lack of a unique dental registration number.
- 5 patient files were issued with the wrong unique registration number.
- 4 patient files were not obtainable from secondary storage/microfilm.
- 1 patient file was not an implant case.

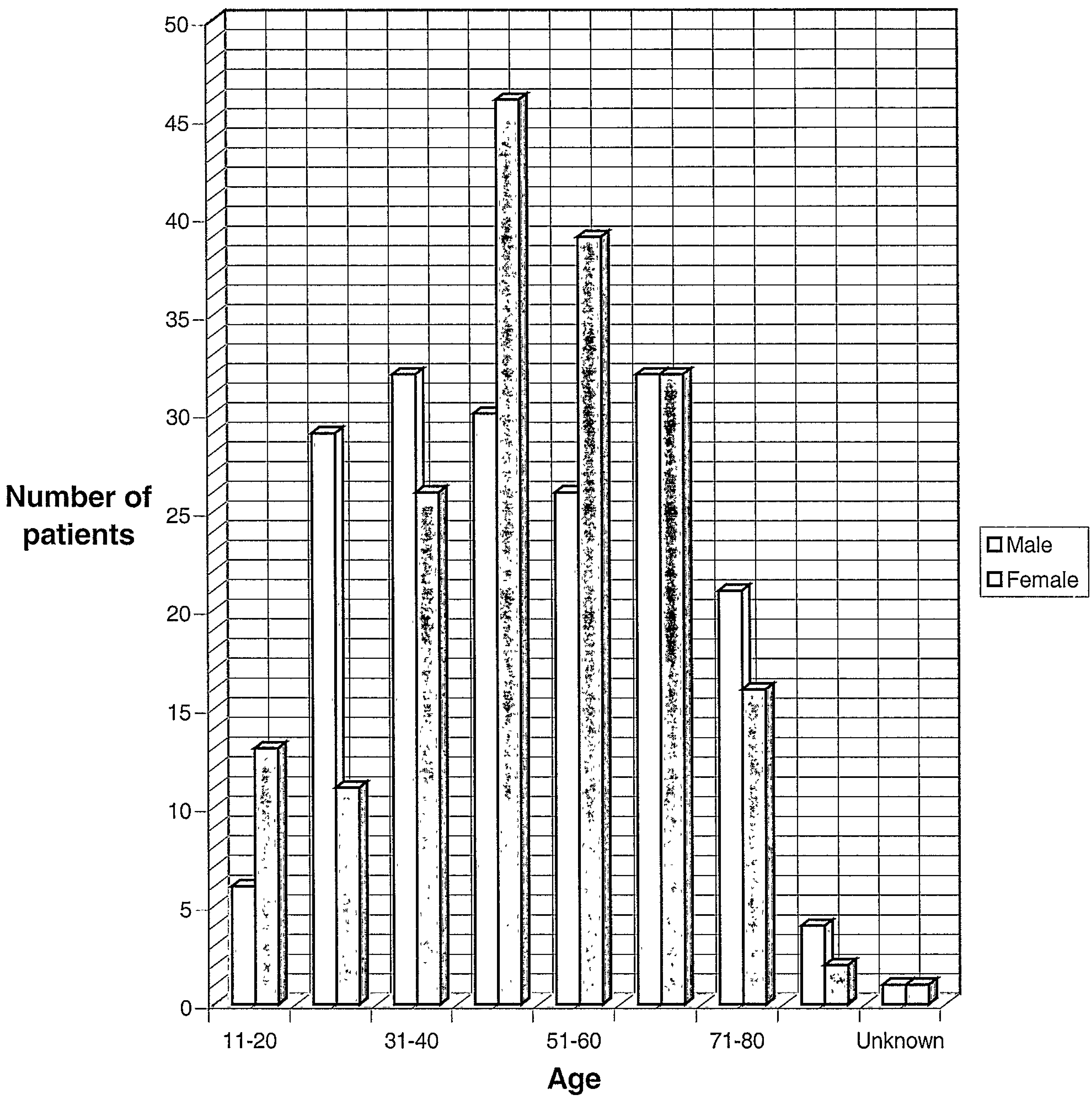
Residual Study Group - 367 patients (mean age 48.8 years).

- 181 Men (mean age 48.2 years) and 186 Women (mean age 49.5years) (Table 1 and Figure 1).
- 108 patients had implant surgery only.
- 259 patients had both implant surgery and received implant prostheses.

Table 1 Age and Gender of Residual Study Group

Age Range	Male	Female	Total
11-20	6	13	19
21-30	29	11	40
31-40	32	26	58
41-50	30	46	76
51-60	26	39	65
61-70	32	32	64
71-80	21	16	37
81-90	4	2	6
Unknown	1	1	2
Sum	181	186	367

Figure 1 Study Group Age and Gender



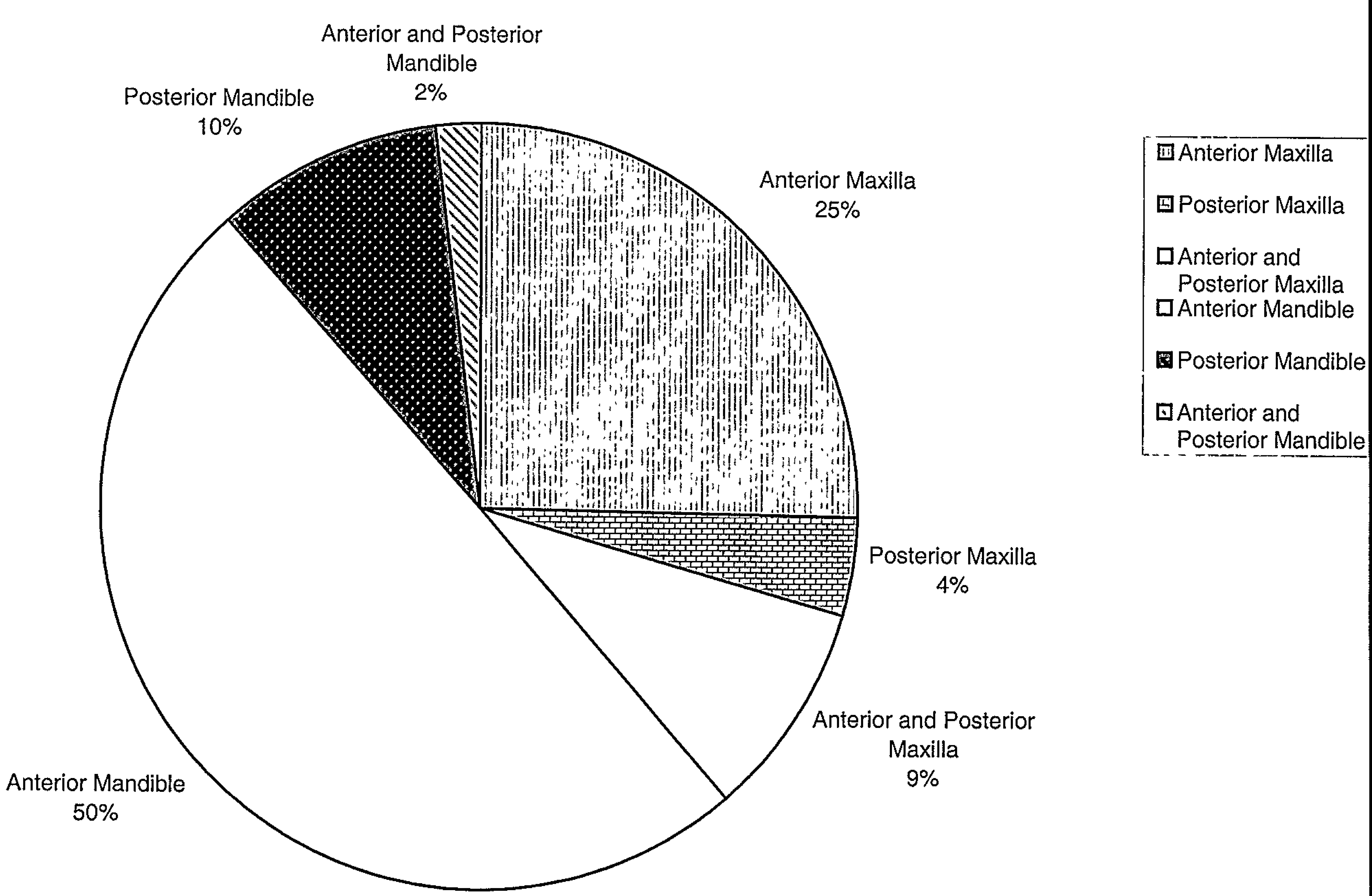
Implants

A total of 1027 Branemark fixtures were placed; 21 wide platform, 1004 regular platform and 2 narrow platform (Table 2). Three hundred and ninety- six fixtures were placed in the maxilla (38.5%); 260 in the anterior maxilla, 42 in the posterior maxilla and 94 documented as maxilla. Six hundred and thirty one fixtures were placed in the mandible (61.5%); 511 in the anterior mandible, 101 in the posterior mandible, and 19 documented as mandibular (Figure 2).

Table 2 Fixture length and platform

Fixture Length (mm)	**6**	**7**	**8**	**8.5**	**10**	**11.5**	**12**	**13**	**15**	**18**	**20**
NP	-	-	-	-	-	-	-	1	1	-	-
RP	-	103	-	22	237	2	-	197	241	146	56
WP	5	-	7	-	8	-	1	-	-	-	-

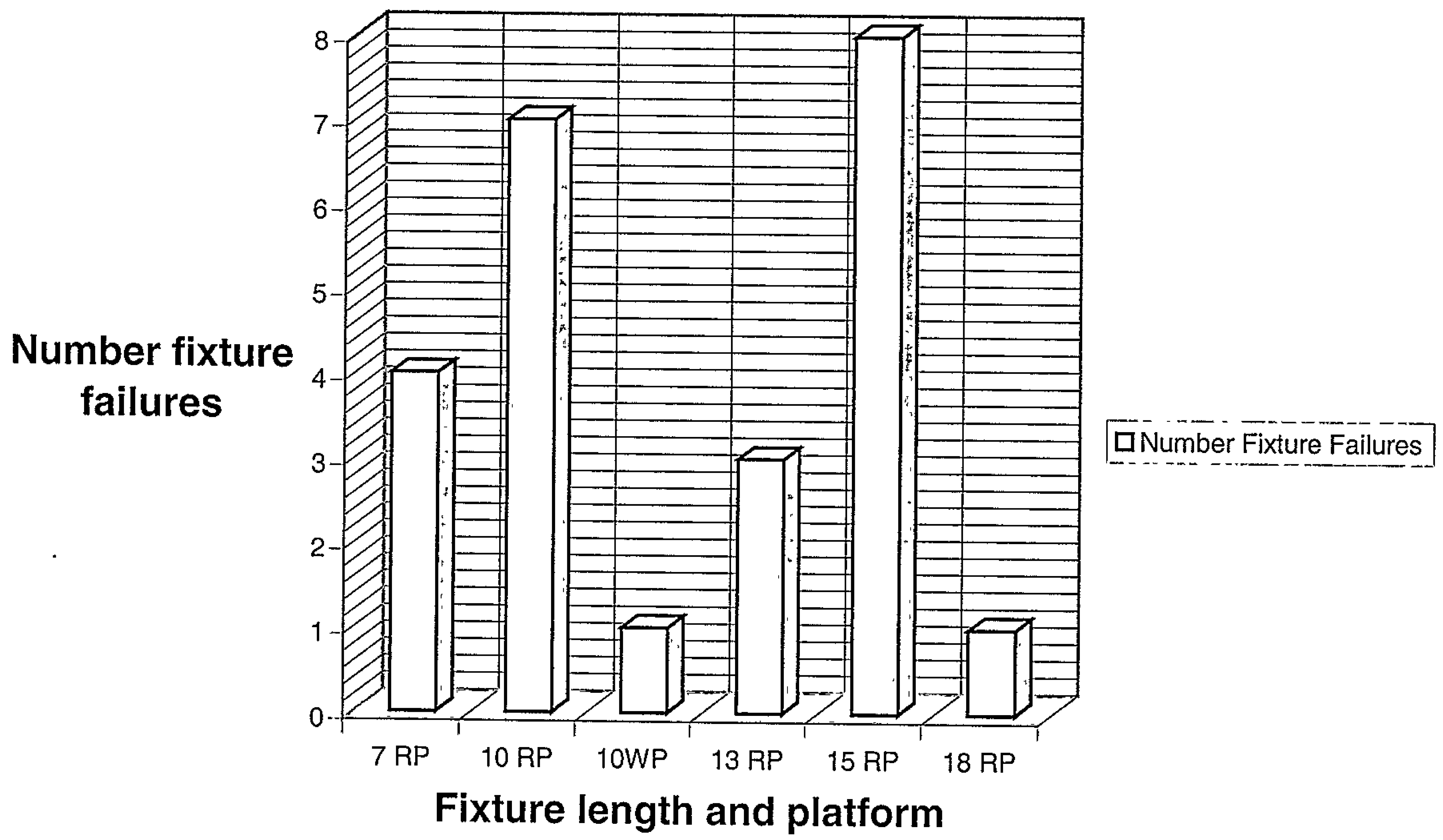
Figure 2 Distribution of fixtures



Fixture Failure

Twenty- three patients (23/367 = 6.3%) had a total loss of 24 fixtures (24/1027 = 2.3%). Fourteen fixtures failed in the maxilla, with an equal number of failures in the anterior and posterior maxilla. Ten fixtures failed in the mandible, with 8 in the anterior mandible and 2 in the posterior mandible. Fixture failure was associated with regular platform (7mm = 4, 10mm = 7, 13 mm= 3, 15mm = 8, 18mm = 1) and wide platform fixtures (10mm = 1) (Figure 3).

Figure 3 Fixture Failures



The time of failure included ;

- Stage I – II - 2/24 (8%)
- Stage II - 4/24 (16%)
- Post Stage II early (within 6 months) - 13/24 (54%)
- Post Stage II late (> 6 months) - 5/24 (22%)

The cumulative incidence of fixture failure was low, with 24 fixtures (2.3%) lost in 23 patients, which agrees with reported implant survival rates (Adell *et al.*, 1990; Lekholm *et al.*, 1990; Bahat, 2000; Jemt, 1991). The percentage of failed fixtures was greater in the maxilla (58%) than the mandible (42%). The posterior maxilla has the greatest occurrence of fixture failure (17%). This would be expected, given the poorer density of bone in this anatomic region. Fixture failure rate for the anterior maxilla and posterior mandible was similar (2%), with the anterior mandible having the lowest percentage of failed fixtures (1.5%). The low failure rates in the anterior mandible can be accounted for by the presence of both high quality and quantity bone, with bicortical fixation facilitating excellent primary implant stability.

The highest incidence of failure was associated with 15mm and 10mm RP fixtures, accounting for almost 62 % of fixture failures. The high number of 10 and 15mm RP fixtures placed distorts the fixture failure figures. As a percentage of fixtures placed, 7mm RP fixtures had the highest incidence of failure, with 3.9% of fixtures failing. This is in agreement with previous studies of higher fixture failures associated with smaller implant lengths (Jemt,1991; Jemt et al., 1990; Goodacre et al., 1999). The shorter implants offer a smaller surface for bone contact and may therefore be prone to biomechanical overload and or periimplantitis may require less time to cause resorption of a critical portion of the established osseointegration ,leading to fixture failure. (Tonetti, 1998).

Seventy eight percent of fixture failures occurred within one year of stage I surgery. Early fixture failure is the inability of the host to achieve osseointegration and can be due to;

- Surgical trauma - Lack of operator surgical experience, thermal trauma (>47 C for 1 minute).

- Impaired healing ability - Such as diabetes, irradiation of jaws, or cigarette smoking. The reported fixture failure rate for non-smokers varies between 2 - 4.76 % and smokers of 9 - 11.76% (Bain and Moy, 1993; De Bruyn and Collaert, 1994).

- Premature loading – It is not the absence of loading per se that is critical for osseointegration, but rather the absence of excessive micromotion at the interface. Excessive micromotion damages tissue and vascular structures, interferes with early scaffold development into fibrin clot and disrupts angiogenesis and promotes healing by repair. The threshold of micromotion beyond which osseointegration will not occur, is suggested to be 100 μm.

- Infection and immunologic factors – Failure to use preoperative antibiotics, bacterial contamination of the implant and or the wound in the course of surgery. (Esposito *et al.*,1999).

- Anatomic conditions – Poor bone quantity and quality. Implant failure rate is higher in type 4 bone (Jaffin and Berman, 1991).

Interestingly, half of the fixture failures were within 6 months of stage II surgery. Current methods to clinically assess fixture integration at stage II surgery include:

- Percussion test- The osseointegration of implants can be assessed by tapping an implant and or abutment with a metal instrument and assessing the nature of the sound and the absence of discomfort (Adell *et al.*, 1981). This method has proven unsuccessful due to the inability to consistently discriminate sound in terms of specific and sensitive criteria.

- Mobility – Detection of mobility cannot be made until gross macroscopic movement is visualized.

- Periotest – Is used to measure implant mobility by percussing transmucosal implant components. Clinical studies indicate a periotest value (PTV) of 5+ represents a potential problem or lack of osseointegration. Note the PTV can be influenced by methodological factors such as angulation, striking point, and abutment length. The periotest lacks sensitivity with a low positive predictive value of 64% and since the negative predictive value is 99%, 1% of integrated implants may be identified as being non-integrated. Clinicians should not use the PTV as their only parameter for determining osseointegration of dental implants at stage II (Drago, 2000).

- Reverse Torque Test - Clinical application of the reverse torque test is guarded. Rotational mobility can be a sign of incomplete bone healing, rather than soft tissue encapsulation. Additional time may be required to allow complete remodeling of the bony interface.

- Radiography – Standardized periapical radiographs are taken to assess the degree of osseous contact to the implant body. The presence of a continuous periimpant radiolucency is a sign of a failure to achieve or maintain osseointegration (Adell *et al.*, 1981).

- Resonance Frequency Analysis (RFA) - Resonance frequency is determined by the stiffness of the bone-implant interface and distance from the transducer to the first bone implant contact. It is clinically sensitive in measuring implant stability and changes in stability. Successful implants have higher RF 8000 – 10000 Hz and failed implants a lower RF 5500 Hz (Sennerby and Meredith, 1998). The application of RFA may be a clinically useful tool to determine both initial implant stability at stage I surgery and secondary implant stability (osseointegration) at stage II surgery, or at the commencement of prosthodontic procedures.

The current study utilized percussion, gross implant stability, and radiographs to determine if fixtures were osseointegrated. Implant mobility was pathognomonic of fixture failure. It is likely the fixture failures that occurred within 6 months of Stage II surgery reflect a lack of sensitivity of current tests to determine failing implants (false negatives) at Stage II surgery. Further development of RFA and new technologies are required to improve clinical diagnostic ability for determination of fixture integration.

Twenty two percent of fixture failures occurred more than 6 months following stage II surgery and represent failure to maintain the established osseointegration. This may be due to;

- Local and systemic factors related to host health, which alter bone metabolism and influence the remodeling capacity of bone.

- Biomechanical overload – Dental implants lack a supportive and proprioceptive periodontal ligament, which leads to a reduced inability to detect heavy occlusal forces and allows force transmission to be applied directly to surrounding bone interface. With functional overload, due to parafunction or poor biomechanical implant or prosthetic design, microfractures may develop in bone around the coronal aspect of the bone- implant interface. When the functional capacity of the bone and or bone-implant interface is exceeded by biomechanical demand, the bone remodeling process is triggered by the accumulation of microcracks, resulting in bone resorption. This loss of bone allows soft tissue invasion into the space between the bone and the implant. If stresses continue to be excessive or bacterial infection is present, bone loss will progresses (Tonnetti and Schmid, 1994).

- Periimplantitis – A plaque-induced site-specific infection, with association of anaerobic bacteria that results in the loss of supporting bone in tissue surrounding a functioning implant. DNA probe analysis indicates the pathogens identified are similar to those found in periodontal disease with moderate levels of A. actinomycetumcomitans, P. Intermedia, P. Gingivalis. The overall frequency of periimplantitis is 4-15 % (Mombelli and Lang, 1998).

  In this study, reasons for late fixture failure was either not stated or attributed to biomechanical overload. It is likely that local and systemic factors relating to bone metabolism, biomechanical overload and periimplantitis were instrumental in late fixture failure.

PERIMPLANT MUCOSAL MAINTENANCE

Periimplant mucosa has a number of biological similarities to the periodontal tissues supporting the natural dentition. The mucosal / implant interface is composed of 3 well-delineated zones; the sulcular epithelium, the junctional epithelium, and the peri-implant connective tissue. The stratified non- keratinised sulcular epithelium has a width of 0.2 – 0.5mm. The sulcular epithelium is continuous with a junctional epithelium that is about 2mm long. The attachment of the epithelial cells and titanium surface is characterized by hemidesmosomes and a basal lamina. The apical portion of the junctional epithelium is separated from the alveolar bone by a collagen-rich but cell-poor connective tissue, which is 1- 1.5 mm thick. The suprabony connective tissue surrounding the implant is composed of circumferential fibers that run parallel to the implant surface. As in the natural dentition, a biologic width of connective tissue is established. (Berglundh and Lindhe, 1998)

This biological similarity of the periimplant mucosa to the periodontium, predisposes the periimplant mucosa to a similar risk of breakdown and disease in the presence of periodontopathic bacteria. It is accepted that periimplantitis, a site-specific periimplant bacterial infection, is a causative factor in periimplant bone loss and fixture failure. The maintenance of periimplant health then becomes central to the long-term success of each osseointegrated fixture.

In the present study, oral hygiene instructions together with scaling and professional prophylaxsis were provided to maintain low levels of plaque and calculus deposits, to promote peri-implant health. Four hundred and forty appointments were provided to remove ISP superstructures and bars for ultrasonic debridement, and to enable scaling of hard deposits from abutments.

Periimplant soft tissue complications

Twenty- two episodes of peri-implant soft tissue complications occurred in 19 patients at an average time of 29 months;

- Perimucositis occurred in 17 cases; 12OD, 3FB, 1 PB and 1 ST, and is the predominant soft tissue complication associated with implants. Tissue hyperplasia is frequently seen if implants are located in an area of nonkeratinised mucosa or if the superstructure is an OD. Management involved removal of the superstructure or bar, scaling of abutments, application of chlorhexidine and abutment screw tightening in 16 cases. One case involved surgical excision of gingivae and another required a free gingival graft.

- Fistulae occurred in 1 ST and 1 PB case. Management of the PB involved removal of the fractured abutment screw, ledermix applied to the abutment screw/implant interface, and placement of healing abutments. The ST case was managed by tightening of abutment screw.

- Granulation tissue developed in the nasal floor of one ST case, and management involved fixture apicectomy.

Prosthesis

A total of 312 ISP were placed in 259 patients: 112 single tooth implant crowns (ST), 47 partial bridgework (PB), 37 full arch bridgework (FB), and 116 overdentures (OD) (Figure 4 and 5). The maxillary incisors accounted for 75 % of single tooth implant crowns, and the maxillary centrals incisors 50% of the ST crowns. PB was approximately equal for the maxilla and mandible, but a greater percentage of FB was placed in the mandible. ODs were placed predominantly in the mandible and involved the use of a bar with clip retention.

Single Tooth Implant Crowns: a total of 112 single tooth implant crowns placed.

Arch

Maxillary	105	(105/112)	= 94%
Mandibular	4	(4/112)	= 3.5 %
Unknown	3		

Position in Arch

Anteriors	91	(91/112)	= 81 %
Posteriors	18	(18/112)	= 16 %

- **Tooth**

Maxillary central incisors	(63/112)	= 56 %
Maxillary lateral incisors	(19/112)	= 17%
Maxillary canine	(9/112)	= 8%
Maxillary premolar	(13/112)	= 12%
Maxillary molar	(1/112)	= 1 %
Mandibular incisor and canine		= 0 %
Mandibular premolar	(1/112)	= 1%
Mandibular molar	(3/112)	= 3%

Partial Bridgework

Maxillary	20
Mandibular	27

Full Arch Bridge

Maxillary	5
Mandibular	32

Overdenture

- Maxillary — 21
  - Bar = 21
    - ⇨ Clips = 15
    - ⇨ Molloplast = 3
    - ⇨ Ceka = 3
  - Ball = 0
- Mandibular — 95
  - Bar = 85
    - ⇨ Clips= 78
    - ⇨ Molloplast = 1
    - ⇨ Ceka = 1
    - ⇨ Dalbo= 5
  - Ball= 3
  - Magnet= 1

Figure 4 Distribution of ISP

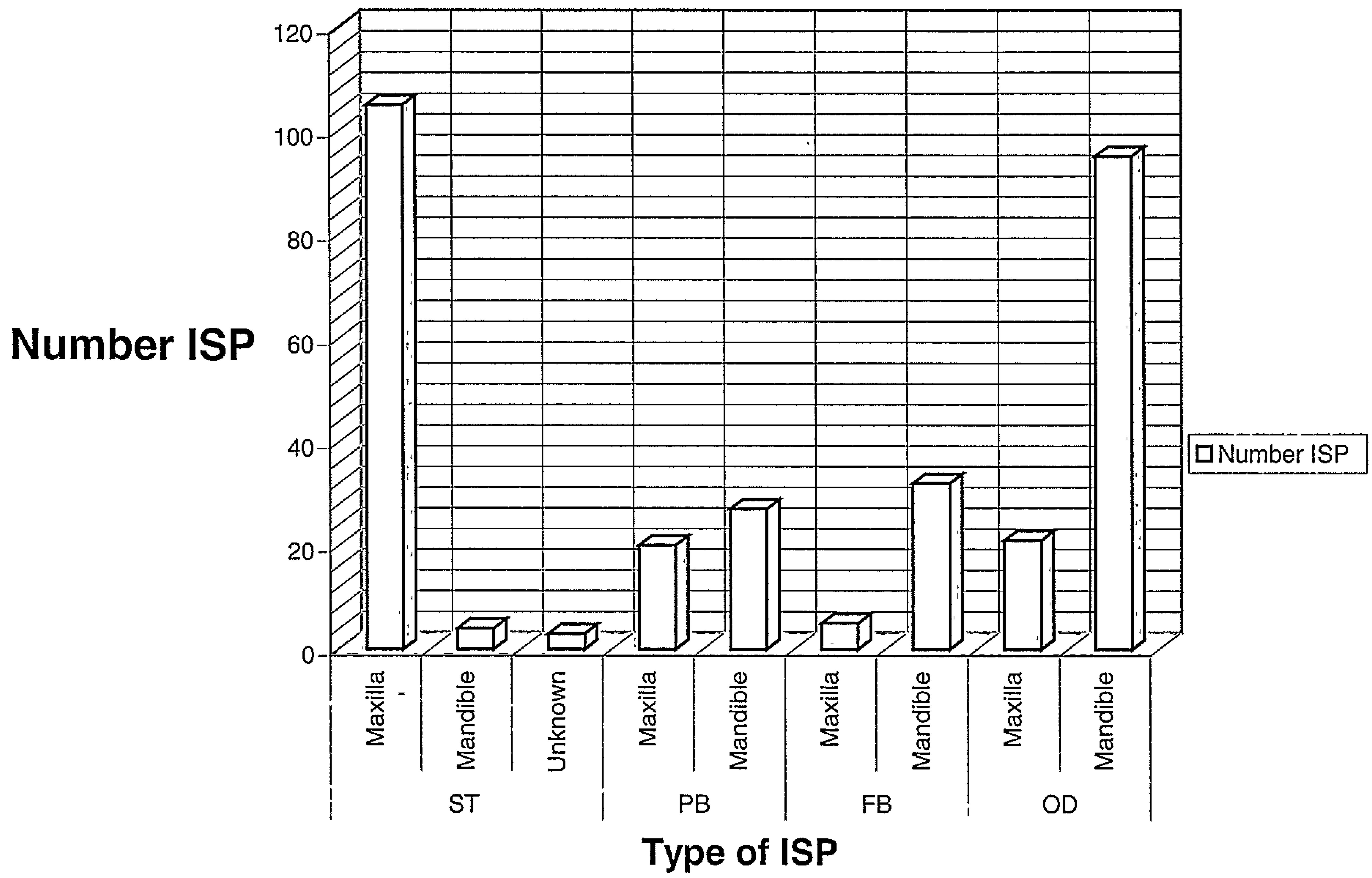
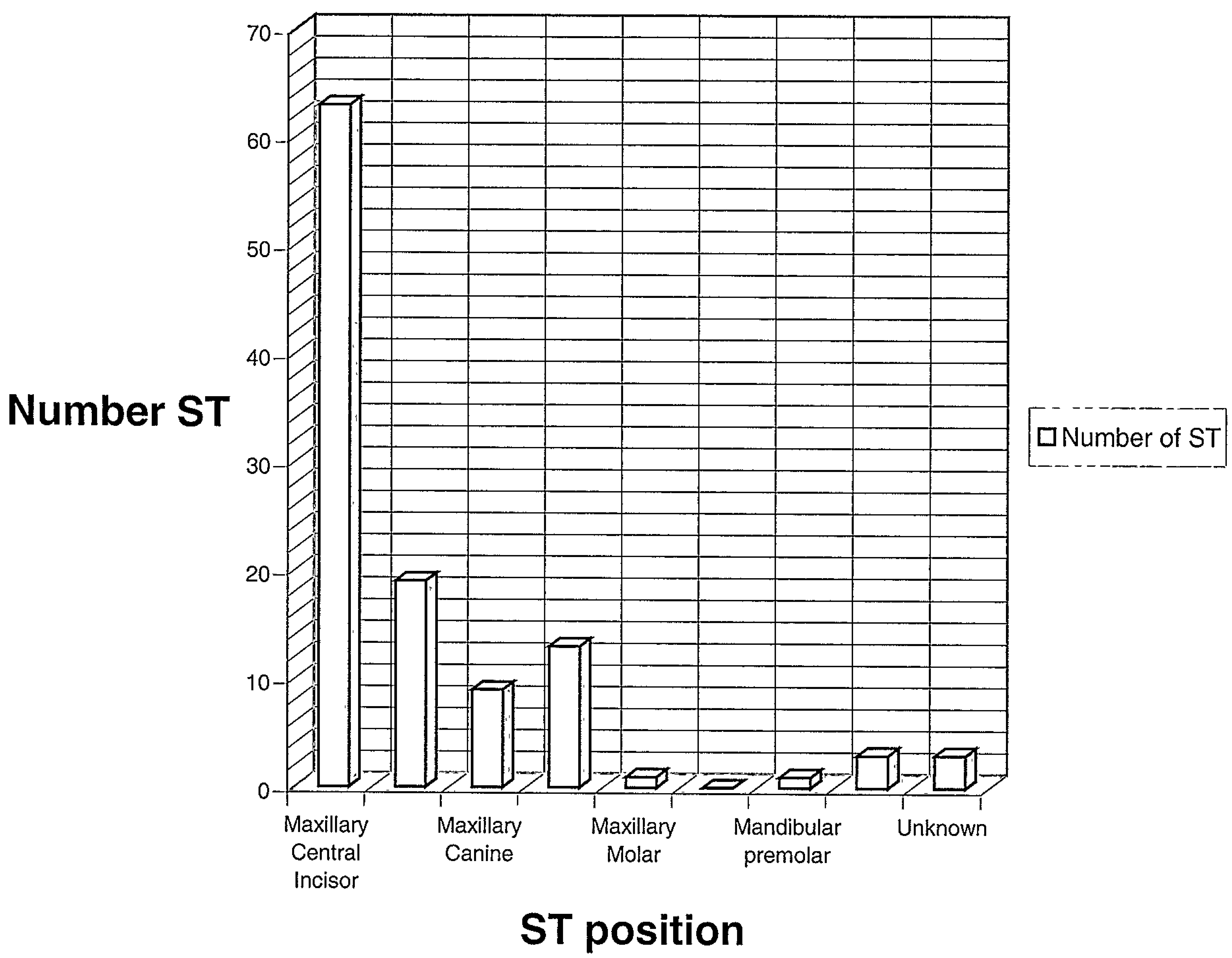


Figure 5 Distribution of ST



MAINTENANCE

Prosthesis Repair

The number of appointments, timing and type of ISP requiring repair is summarized in Table 3. One hundred and two patients (39%) required a total of 380 appointments. One third of the patients required a single ISP repair, and two thirds required 2-10 ISP repairs, with more than 10 repairs an infrequent occurrence. Only 17 % of all repairs occurred within the first year of prostheses service, and 68% of all repairs occurring within the first 5 years. A high repair requirement existed for FB and OD, and a low incidence of repair for ST and PB. The increasing order of prosthesis repair required according to type of ISP was: ST, PB, FB, OD. OD required the highest incidence of repairs, with 67% of all OD requiring repair.

Table 3 Repair – appointments, timing and prosthesis type

a. Repair Appointments		b. Timing of Repair		c. Prostheses Requiring Repair	
Number of repair appointments required.	***Number and percentage of patients with repaired ISP.***	***Time since issue of ISP. (months)***	***Number and percentage of repair appointments***	***Type of ISP***	***Number and percentage of ISP requiring repair.***
1	32 of 102 = 31 %	<6 months	40 of 380 = 11 %	ST	11 of 112 = 10 %
2-5	47 of 102 = 46 %	7-12	26 of 380 = 7 %	PB	8 of 47 = 17 %
6-10	19 of 102 = 19 %	13-24	60 of 380 = 16 %	FB	21 of 37 = 57 %
11-15	1 of 102 = 1 %	25-36	54 of 380 = 14 %	OD	68 of 116 = 59 %
16-20	3 of 102 = 3 %	37-48	47 of 380 = 12 %		
Total number patients with repaired ISP	102	49-60	32 of 380 = 8 %		
Percentage of patients requiring repair of ISP	102 / 259 = 39%	>60	121 of 380 = 32%		
		Total repair appointments	380		

REPAIR CATEGORIES

ISP repair procedures are summarized in Table 4.

Table 4 ISP Repair procedures

Repair Category	Number of Repair Episodes				
	<20	20-39	40-59	60-80	>80
Gold screw fracture	5				
Gold screw replacement	14				
Abutment screw fracture	8				
Abutment screw replacement	18				
Abutment replacement	6				
Framework fracture	3				
Framework repair	3				
Clip fracture	7				
Clip replacement		31			
Magnetic keeper replaced	2				
Magnet replaced	2				
Prosthetic tooth fracture (acrylic)				70	
Prosthetic tooth replacement ISP (acrylic)			54		
Prosthetic tooth replacement opposing prosthesis (acrylic)	17				
Occlusal addition ISP		31			
Occlusal addition opposing prosthesis	4				
Acrylic resin base fracture ISP		20			
Acrylic resin base fracture opposing prosthesis	3				
Reline ISP					97
Reline opposing prosthesis		37			
Precision attachment fracture	6				
Precision attachment replacement	10				
Bar fracture	12				
Bar repair	8				
New bar	3				
Ball O ring replacement	2				
Molloplast renewal	10				

- ***Prosthetic Screw Fracture*** - Five gold screw fractures occurred in 4 cases; 3 associated with OD and 1 PB. The earliest gold screw fracture occurred at 26 months, the latest at 126 months, and at an average period of 56 months. Eight abutment screw fractures occurred in 7 prostheses, 4 associated with OD, 2 PB and 1 FB. The earliest abutment screw fracture occurred at 9 months, the latest at 83 months, with an average period of 43 months. Three cases of abutment screw fracture also had gold screw fractures.

- *Prosthetic Screw Replacement* - Fourteen gold screws were replaced in 9 prostheses; 7 associated with ODs and 2 with PB. Replacement of the gold screw was due to fracture in 5 cases and in 9 cases as a precautionary measure as a result of a loosened screw. The earliest gold screw replacement was at 20 months and the latest 126 months, with an average period of 53 months. Abutment screws were replaced in 19 prostheses; 8 ST, 5 PB, 4 OD, 2 FB. For the ST; 3 abutment screws were bent, of which two were related to a history of trauma, 1 was associated with crown remake following porcelain failure of a cement-on crown, and 1 a change from a titanium abutment screw to the newer gold abutment screw, and 3 abutment screws had a history of screw loosening. Partial bridges, FB and OD required abutment screw replacement due to fracture or as a precautionary measure due to a history of repeated abutment screw loosening. The earliest replacement of an abutment screw occurred at 9 months, the latest at 106 months, with an average period of 38 months. Prosthetic screw fractures are infrequent, with a greater number of abutment screws than gold screw fractures occurring.

Abutment screw fractures occurred earlier (mean 43.4 months) than gold screw fractures (56.4 months). Screw fractures are more common in the OD than bridgework, and no screw fractures were associated with ST. A greater number of screws are replaced than fractured, as a precautionary measure for a prosthesis with a history of repeated screw loosening. Abutment screw replacement is greater than gold screw replacement, with abutment screws replaced earlier than gold screws.

- *Abutment replacement* - A total of 3 abutments were replaced in 3 prostheses, 2 associated with a ST and one an OD. A ST abutment was changed at 5 years to improve biomechanical loading, and a second ST abutment was required with crown remake at 18 months. The abutment replacement in the OD prostheses was required at 14 months with a change from a bar to ball retention. Abutment replacement is an infrequent maintenance procedure, associated with a change of prosthesis design.

- *Superstructure fracture* - A single FB had 3 superstructure fractures after 26 months, and was later converted to an OD. Superstructure fracture is extremely rare and is related to inappropriate biomechanical design.

- ❑ ***Overdenture Clips*** –Thirty-one clip replacements were necessary in 23 OD, 20 mandibular OD and 3 maxillary OD. Single clip replacement was necessary in 18 OD, and 5 OD required multiple clip replacements. The earliest clip replacement took place at 9 months, the latest at 125 months, at an average period of 60 months. Clip replacement was necessary because of fracture in 7 prostheses, loose clips in 3 prostheses, determined at review and reline in 13 prostheses. The 7 clip fractures occurred in mandibular OD. The earliest clip fracture was at 5 months post issue and the latest at 112 months, with an average period of 56 months.
  The incidence of clip fracture (6% OD) is less than clip replacement, with up to 25% OD requiring clip replacement over the long-term. Clip replacement has frequently been performed with subsequent relining of acrylic-based OD.

- ❑ ***Overdenture Magnet*** - The use of OD magnets was restricted to a single mandibular OD case. Corrosion of the magnets required their replacement to be made twice, at 30 and 48 months post issue.

- ❑ ***Prosthetic acrylic tooth repair*** - A single ISP prosthetic tooth repair was required for 16 patients, and multiple tooth repairs were necessary for 12 patients. Prosthetic tooth replacement for tooth fracture occurred with greater incidence with FB (12/37=32%) than OD (14/116= 12%), and less so with the PB (3/47 = 6%) ISP. Prosthetic tooth replacement for the opposing full upper prosthesis was less frequent (17 versus 54) than for the ISP. Prosthetic tooth replacements for tooth fracture occurred on average at 3.75 years, and for the opposing prostheses at 5.25 years. Reset of ISP was an infrequent (8 patients) procedure required for acrylic teeth with excessive wear, and was required after approximately 4.75 years of service.
  The high incidence of prosthetic tooth fracture associated with FB questions the appropriateness of superstructure design in relation to acrylic tooth retention. The use of metal posts has been incorporated in the superstructure design to aid retention of prosthetic teeth (Henry *et al.*, 1995).

- ❑ ***Porcelain Fracture*** - Porcelain fractures were associated with ST only, with 5 in the anterior maxilla and 1 in the posterior maxilla. The earliest porcelain fracture was at 1-month and the latest at 20 months, with an average of 10.7 months. Three ST crowns required remake, 2 ST crowns required porcelain addition and 1 ST crown required no treatment.

  The fracture of veneering porcelain was uncommon, and associated with only 4.5 % of ST and no PB. Screw retention of ST would allow the refacing of porcelain, where porcelain fracture had occurred. The dilemma for cement-on ST is retrievability. This may be overcome with the use of provisional cements, cross pinning, or venting to access abutment screws. However if a porcelain fracture is experienced in a non-retrievable ST, then sectioning and sacrifice of the crown is made, together with an attempt to avoid damaging the abutment, in order to remake the ST. (Jemt *et al.*, 1990)

- ***Occlusal Addition*** – Thirty- one occlusal additions were required to increase the vertical dimension of occlusion. Fifteen occlusal additions were made for OD and 5 for FB. Ten prostheses required a single occlusal addition and 5 required multiple occlusal additions. The material used was amalgam in 9 cases and acrylic in 22 cases .In 3 patients acrylic was added to the occlusal surface of the opposing prosthesis (2 FB and 1 PB), in one case to increase the VDO and the other two to improve occlusal contacts.

  The loss of vertical dimension is due to the wear of acrylic resin of the FB or OD. A basic tenet of restoring dental implants was that the implant must be protected from the shock of occlusal function or parafunction. Avoidance of ceramic or metallic occlusal surfaces was assumed to be of critical importance. Acrylic resin was recommended by Branemark and coworkers because of a perceived cushioning of occlusal load, to minimize load transfer to implant-bone interface. With the high fixture success associated with partially endentulous cases using porcelain fused-to-metal materials, one must question the validity of acrylic resin use for ISP. The maintenance of the vertical dimension of occlusion could be achieved by the use of porcelain or gold on the occlusal surfaces of ISP.

- ***Acrylic base fracture*** - Fracture of the acrylic resin base occurred in 14 ODs and 1 PB. Multiple repairs of the acrylic base were required for 3 ODs. The earliest fracture of the acrylic base occurred at 11 months, the latest at 98 months, at an average period of 56.5 months. The opposing prosthesis acrylic base fracture occurred with 3 complete maxillary dentures at a variable period of 13 to 104 months. Acrylic resin base fractures occurred in 12% of OD prosthesis at an average period of 4.5 years. Some consideration must be given to methods of strengthening the base, to further minimize ISP base fracture (Keiner *et al.*, 2001).

- ***Reline*** – Thirty- three OD (28%) required 97 relines, with 19 OD requiring multiple relines, at an average period of 47 months. Seventy relines were performed within the first 5 years ;

  - < 12 months = 15 relines
  - 1-2 years = 13 relines
  - 2-5 years = 42 relines
  - 5-10 years = 25 relines
  - > 10 years = 2 relines

Twenty-six opposing complete maxillary prostheses required 37 relines, with 8 F/- requiring more than one reline, at any average period of 45 months. Twenty-two relines were performed within the first 5 years;

- < 12mths = 9 relines
- 1-2 years = 5 relines
- 2-5 years = 8 relines
- 5-10 years = 12 relines
- > 10 years = 1 reline

The time interval at which the opposing prosthesis is relined does not reflect the age of the prosthesis, but the time from the issue of the ISP. Reline procedures for ODs are more than twice as common as reline procedures for the opposing prosthesis (F/). Seventy percent of relines for OD and 60% opposing complete dentures are performed within the first 5 years. Given that the OD gains significant support from the tissues, a reline of the denture base represents no additional prosthetic maintenance compared with a conventional complete denture, which also requires periodic reline for optimal fit and stability.

- ❑ ***Precision attachment*** - Six Dalbo matrix fractures occurred in 4 hybrid prostheses, and 1 prosthesis experiencing multiple fractures, at an average period of 32 months. Precision attachment replacement was required in 10 prostheses at an average period of 32 months ;

  - Dalbo to ERA = 1
  - Ceka to Dalbo = 1
  - ERA matrix replacement = 4
  - Dalbo matrix replacement= 3
  - Dalbo spring replacement = 1

  All fractures encountered with precision attachments involved Dalbo matrices, and this initial experience lead to the subsequent use of the ERA precision attachment in hybrid dentures.

- ❑ ***Bar Fracture*** - Twelve implant bar fractures occurred in 7 patients, 5 maxillary and 2 mandibular OD prostheses, at an average period of 32 months. Four cases had multiple bar fractures. Seven of the bar fractures were located in the cantilever section. Bar fractures were repaired by resoldering for 9 cases and remake in 3 cases.

  The use of cantilevers for overdentures converts an implant- retained prosthesis to an implant-supported prosthesis. The reduction of tissue support directs a greater proportion of the occlusal load, in function and parafunction, through the prostheses, supporting bar, abutment components and fixtures. Fatigue failure of cantilever bar extensions is then a sequelae afforded by the lost tissue support for the OD.

- *O-Ring replacement* - One of the three ball- retained mandibular OD required replacement of the rubber O –ring on 2 occasions at 25 and 73 months, in association with reline procedures.

Due to the small number of OD cases treated with ball attachments or magnets, the information gained for OD maintenance is limited for these types of prostheses.

- *Molloplast retention* – Five OD prostheses received 10 molloplast additions for purposes of retention, at an average period of 45 months.

REPAIR TIMELINE

Timeline of prosthetic repair required since ISP issue. (Table 5)

Table 5 Timeline for prosthetic repair.

Average time in years.	**Prosthetic complication and Repair – most likely complications.**
<= 1	Porcelain fracture
1-2	Nil
2-3	Bar and precision attachment fracture
3-4	Abutment screw fracture and replacement Reline ISP acrylic tooth fracture
4-5	Bar clip fracture Gold screw fracture and replacement
> 5	Acrylic tooth addition

ADJUSTMENTS

An adjustment is defined as treatment that can be performed without repair, remake or addition to the prosthesis. Prostheses adjustment procedures are summarized in Table 6.

Table 6 ISP Adjustments

Adjustment type	**Number adjustments performed**
Occlusal adjustment	247
Contour modification ISP	247
Contour modification OP	41
Gold screw tightening	25
Abutment screw tightening	37
Crown recementation	14
Bar clip tightening	32
Magnetic keeper adjustment	4
Precision attachment adjustment	4
Ball tightening	5

- ❑ *Occlusal adjustment* – An occlusal adjustment involves the removal of restorative material from the occlusal surface of a prosthetic tooth. A total of 247 occlusal adjustments were required for 199 prostheses; 53 ST, 101OD, 22 PB, 23 FB. As a percentage of prostheses placed, 87% of OD required occlusal adjustment, followed by FB with 62% and equal adjustment provided for 47% of ST and PB. More than half of the occlusal adjustments were provided within the first year. (Table 7).

Table 7 Occlusal adjustment ISP

Period following prosthesis issue (months)	Number of occlusal adjustments
<= 6	120
7-12	20
13-24	31
25-36	13
37-48	10
49-60	17
> 60 months	36

- *Contour modification* - Contour modification is the removal of restorative material from the base (tissue facing surface) of the prosthesis. For FB and PB, contour adjustments are performed to improve oral hygiene to facilitate plaque removal. The OD contour adjustments are required to eliminate areas of acrylic resin on the fitting surface causing soft tissue pathology and pain. A total of 247 contour modifications were required in 80 ISP prostheses; 5 ST, 70 OD, 1 PB and 3 FB. As a percentage of prostheses placed, 67% of OD, 14% FB and 3 % or less of ST and PB required contour modifications. Half of contour modifications are performed within the first year of prosthesis issue, with the remainder occurring at a scheduled review or following reline (Table 8). Forty-one contour modifications were required for sixteen opposing F/-, where 12 opposed an OD and 4 a FB. Sixty three percent of contour modifications to the F/- were performed within the first year of ISP issue (Table 9).

Table 8 Contour modification ISP

Period following prosthesis issue (months)	**Number of contour modifications**
< = 6	97
7-12	24
13-24	34
25-36	19
37-48	14
49-60	19
>60	43

Table 9 Contour modification of opposing F/-

Period following ISP issue (months)	**Number of contour modifications**
< = 6	10
7-12	16
13-24	3
25-36	0
37-48	1
49-60	3
>60	8

Occlusal adjustment and contour modifications represent significant maintenance requirements for ISP. Within the first year of service, a large percentage of OD will require review and adjustment to the both the fitting and occlusal surfaces. These procedures may be simple to perform and require a small amount of clinical time. The reason for adjustment of the OD base, and occlusion, is soft tissue discomfort associated with localized mucosal inflammation (pressure spots) and or decubitis ulceration. As such, contour adjustments for OD are no different to the requirements of adjustment for a newly issued conventional complete denture.

❑ *Prosthetic screw adjustment*

- Twenty-five loose gold screws required tightening in 15 OD and 2 PB, with 3 OD requiring multiple tightening (Table 9). Gold screw loosening is predominantly associated with OD, and presents clinically as loosening of the OD bar.

- Thirty-seven loose abutment screws required tightening in 6 OD, 1 FB, 3 PB, and 12 ST (Table 10). Abutment screw loosening is most commonly associated with ST, and this underlies the advantage of retrievability for a screw-retained prosthesis to facilitate abutment screw tightening. With the external hex configuration of the Branemark fixture, the axial preload of the abutment screw is a determining factor for the stability of the implant-abutment connection. The original titanium abutment screws experienced loosening in a high percentage of single tooth implants, and required tightening more than once in a smaller percentage of implants. This problem has been resolved with the fabrication of a gold palladium abutment screw. This gold abutment screw has an increased stem length that aids in attaining optimal elongation, and short thread lengths that reduce friction. The gold alloy also has a lower coefficient of friction and is not subject to galling. The advent of the Cera-One abutment and the use of a gold screw together with the use of electronic torque has reduced the incidence of abutment screw loosening in ST crowns.

Table 9 Gold screw tightening

Period following ISP issue (months)	Number of gold screws tightened
< = 6	3
7-12	5
13-24	7
25-36	3
37-48	0
49-60	1
>60	6

Table 10 Abutment screw tightening

Period following ISP issue (months)	Number of abutment screws tightened
< = 6	8
7-12	2
13-24	5
25-36	1
37-48	12
49-60	2
>60	7

- ❑ ***Crown recementation*** – Seven maxillary ST required recementation, 3 of which required multiple recementation, at an average period of 43 months. Reasons for crown decementation included traumatic injury, unfavorable loading associated with angulated abutments, microleakage associated with failure to seal crown vent hole, and the use of provisional cements.

- ❑ ***Overdenture retention adjustment*** – Bar clip adjustment was required to improve retention in 23 OD. Five OD required multiple clip tightening, with the average period till clip adjustment at 45 months. Ball tightening was required in a single case, where the OD balls were tightened on 5 occasions within the first 2 years. Magnetic keeper tightening was required on 4 occasions in a single OD case. Precision attachment adjustment was required in 2 cases, with adjustment of a Ceka matrix and Dalbo spring.

REMAKE

Investigators have reported on the success of implant prostheses on the basis of "continuous prosthetic stability". Continuous prosthesis stability refers to the ability of the patient to continue to wear an implant-supported prosthesis, without the return to a conventional denture. The reported figures for continuous prosthesis stability vary from 79 % to 100% (Adell *et al.*, 1981; Zarb and Schmitt, 1990; Wyatt and Zarb, 1998). To maintain a high level of prosthetic stability, prosthetic remake has been required in a number of studies. Others have remade full arch prostheses to restore the vertical dimension of occlusion. (Carlson *et al.*, 1994).

Remake - Prosthesis remake is the construction of a new prosthesis with a similar design to the original prosthesis. A single PB was remade at 22 months due to the loss of veneer facings. Four ST were remade between 3 and 61 months of use. Three maxillary incisor ST remakes were necessary because of porcelain fractures (2 PFM, 1 PJC) and the fourth ST crown remake was necessary following a change of prosthetic abutment. Twelve maxillary and 6 mandibular OD required remake at an average period of 66 months (Table 11). Approximately 1 in 6 ODs required remake after a 5-year period. PB and ST rarely required remake (2%).

Conversion remake - Prosthesis conversion remake involves fabrication of a new prosthesis to a new prosthetic design. A single PB was converted to a FB, and 7 FB were converted to an OD. Nineteen percent of FB required conversion remake at an average time of 44 months (Table 11). Approximately 1 in 5 FB were converted to an OD, due to patient preferences with respect to aesthetics, phonetics and hygiene requirements. Where the FB was maintained, no remake was required.

Table 11 Prosthesis Remake

Prosthesis	**Remake**		**Conversion Remake**	
	Required	**ISP %**	**Required**	**ISP %**
ST	4	3	0	0
PB	1	2	1	2
FB	0	0	7	19
OD	18	16	0	0

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