Mandibular Two-Implant Overdentures: Prosthodontic Maintenance Using Different Loading Protocols and Attachment Systems

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Purpose: The aim of this research was to determine the long-term prosthodontic maintenance requirements of mandibular two-implant overdentures using different loading protocols and attachment systems. ***Materials and Methods:*** A total of 106 participants were allocated randomly to one of four different implant systems (Steri-Oss, Southern, Straumann, or Brånemark). Three different loading protocols (2, 6, and 12 weeks) were used with six different ball abutment patrices and their respective matrices (Steri-Oss rubber, Straumann gold, Straumann titanium, Brånemark gold, Southern plastic, and Southern gold/platinum). Prosthodontic maintenance events were documented prospectively from baseline until the 8-year recall according to predefined categories. ***Results:*** After 6 years, 90 participants attended recall and, thereafter, 68 participants were followed for 8 years. No significant differences were found between the number of prosthodontic maintenance events and the loading protocol used. Steri-Oss rubber matrices had the highest mean number of maintenance events at 32.2 ± 14.5 events, followed by the Brånemark gold matrices at 28.8 ± 12.6 events. The Southern plastic matrices had a significantly lower mean number of maintenance events (8.7 ± 4.2) when compared with all other groups. Over a 6-year period, the matrices with the best longevity were Straumann gold at 3.9 ± 2.1 years. Straumann gold matrices also lasted significantly longer than all other matrices ($P < .05$). Southern gold/platinum, Brånemark gold, and Southern plastic matrices all lasted significantly longer than the Straumann titanium and Steri-Oss matrices ($P < .05$). The mean time to reline for overdentures was 3.37 ± 2.06 years; remaking of overdentures peaked by year 7, with a mean time to remake of 5.81 ± 2.04 years. ***Conclusion:*** Early loading protocols do not influence long-term prosthodontic maintenance requirements of unsplinted mandibular two-implant overdentures. By contrast, attachment systems do influence prosthodontic maintenance, particularly with regard to the type of matrices used. *Int J Prosthodont 2011;24:405–416.*

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Mandibular two-implant overdentures opposing maxillary complete dentures have been documented as an effective treatment option to restore the edentulous mandible for more than 20 years.[1,2] However, the proposal that this treatment option should be the standard of care for edentulous patients is debatable.[3] Controversy is fueled by different philosophies globally, locally constructed standards of care, and the long-term outcomes of more complex interventions with prosthodontic rehabilitations.[4,5] On the other hand, there is consensus among researchers that short-, medium-, and long-term prosthodontic

maintenance requirements should be identified and discussed with patients prior to commencing treatment.[6–8] This helps patients to understand future prosthodontic fees that will be incurred.[8] Earlier evidence points toward prosthodontic maintenance of implant overdentures being elevated when compared with full-arch fixed implant prostheses.[7,9] Therefore, it is often argued, sometimes against strong evidence, that the initial cost-effectiveness of mandibular two-implant overdentures can be outweighed by their long-term maintenance burden.[7,10–14] One cost minimization analysis in a long-term study comparing full-arch fixed implant prostheses and overdentures in the mandible concluded that overdenture therapy for edentulous patients is a more cost-effective treatment.[13] Prosthodontic maintenance requirements for mandibular two-implant overdentures are also directly related to the attachment system used; however, there are a limited number of attachment systems that have both short- and long-term clinical research substantiating their use.[15–19] In fact, it has recently been identified that only a few studies have prospectively compared prosthodontic maintenance for periods longer than 5 years after delivery of the prostheses.[20] Well-designed longitudinal studies are encouraged to establish evidence-based treatment planning.

Abbreviated loading protocols using overdentures in edentulous patients are evidence-based.[21] However, these studies include those that have focused on surgical and peri-implant outcomes, cost effectiveness, and patient satisfaction with mandibular two-implant overdentures.[22–29]

In contrast, there is a dearth of literature focused on the influence of loading protocols on unsplinted implants and ball attachment systems and their long-term prosthodontic maintenance requirements. Previous research comparing conventional and early loading with ball attachments found more prosthodontic maintenance events were required for the early loading group, although this was not statistically significant.[30] A study of immediate loading with mandibular bar overdentures indicated that prosthodontic maintenance requirements, and therefore treatment costs, may increase when abbreviated loading protocols are used.[29] There is an absence of research with controlled evaluation of the prosthodontic implications of early loading protocols using mandibular implant overdentures.

The aim of this research was to determine the up to 8-year maintenance requirements of mandibular two-implant overdentures on unsplinted implants opposing maxillary complete dentures using conventional and early loading protocols with different attachment systems.

Materials and Methods

One hundred six edentulous participants (38% men, mean age: 65.3 ± 7.4 years, mean edentulous period: 34.7 ± 13.4 years, 8 to 15 mm of residual anterior mandibular bone) with a history of difficulties with their complete dentures were selected for an ongoing randomized control trial in the Oral Implantology Research Group, Sir John Walsh Research Institute, School of Dentistry, University of Otago, Dunedin, New Zealand. Standardized inclusion and exclusion criteria were applied.[31] Ethical approval was obtained from the Lower South Ethics Committee, New Zealand, on an ongoing basis in view of the length of the clinical trial. All participants gave informed consent and had previously worn more than three sets of replacement complete dentures. On average, each participant had worn his or her complete dentures for 11.2 ± 6.8 years. Groups did not differ significantly by age, number of years edentulous, or the number of previous dentures.

Participants were allocated randomly to one of four different implant systems.[32] One of these implant systems used a turned titanium implant surface (original conical Brånemark implant, Nobel Biocare). The other three implant systems (Southern Implants, Steri-Oss, and Straumann) had titanium surfaces roughened to varying extents: sandblasted acid-etched; acid-etched machined; and sandblasted, large-grit, acid-etched, respectively. Further details regarding the participants and surgical protocols have been provided in previous reports.[15,22–26]

Loading Protocols

Participants were allocated randomly to one of three loading protocol groups. The conventional loading groups involved a 12-week loading protocol, whereas the early loading groups were divided into 2- and 6-week loading protocols.[33] Twelve participants were allocated to each loading protocol, except for the Brånemark group, which had only 10 participants because of funding reasons and therefore limited itself to only the 2-week loading group. Southern and Straumann implants were allocated to all three loading groups, whereas Steri-Oss implants were loaded at either 6 or 12 weeks and Brånemark implants were loaded at 2 weeks only.

Initially, new diagnostic maxillary and mandibular complete dentures were fabricated for each participant following recognized prosthodontic techniques.[34] Following implant placement, 12-week and 6-week group participants had healing abutments placed and did not wear their mandibular

complete dentures for 10 days before tissue conditioners (Visco-gel, Dentsply) were applied. After the allocated healing periods, the respective ball abutments (patrices) were placed, closed-mouth reline procedures (Impregum, 3M ESPE) followed, and the matrices were added to the intaglio surface of the overdentures in the laboratory. Participants in the 2-week loading protocol groups had their ball abutments placed at surgery, and denture tissue conditioners were placed immediately following generous relief of the undersurface of the dentures. The 2-week healing groups were permitted to use their mandibular dentures with a soft diet but removed them nocturnally. After 2 weeks, these groups underwent closed-mouth reline procedures to add the matrices to the intaglio surface of the overdentures.

Attachment Systems

Each participant was eventually provided with one of six overdenture attachment systems (Fig 1). The Brånemark and Straumann patrices consisted of 2.25-mm-diameter titanium alloy ball abutments. The two Southern patrices used were 3.95-mm titanium nitride–coated ball abutments for the plastic matrices and 2.25-mm titanium ball abutments for the gold/platinum matrices. The Steri-Oss group had 2.2-mm-diameter ball abutments.

The matrices used on the intaglio surface of the overdentures included the original Brånemark gold and Steri-Oss rubber ones. The Steri-Oss rubber matrices became obsolete during the study period and also required excessive prosthodontic maintenance compared to the other systems.[26,31] These participants at the 5-year recall were offered the opportunity to have their attachment systems converted to the Locator attachment system (Zest Anchors) from the beginning of year 6 until the 10-year recall. The Straumann groups had titanium matrices with stainless steel springs or gold matrices, which were the original Dalla Bona type and not the elliptical ones currently available. The Southern groups included plastic matrices or gold/platinum alloy matrices (Ceka).

By design, the Steri-Oss, Straumann titanium, and Southern plastic matrices could not be activated, only replaced. Conversely, the Brånemark gold, Straumann gold, and Southern gold/platinum alloy matrices could all be activated. Controlled activation of these matrices was achieved with the respective activating tools provided by the manufacturer. A participant complaining of poor retention would usually have both matrices activated or replaced at the same visit, unless it was completely clear which matrix was poorly retentive.

Prosthodontic Maintenance

Events were documented prospectively using categories and standardized evidence-based criteria for years 1 to 8.[35,36] Prosthodontic maintenance treatment was carried out mostly by one researcher. However, during the first year of service[15] and later years, maintenance treatment was also performed by graduate prosthodontic students who were calibrated in applying the same criteria. Matrix maintenance events were separated from general overdenture maintenance and were recorded per patient. Overdenture maintenance that was recorded included fractures, puncture fractures, and relines or remakes of the original overdenture. The need for relining the mandibular overdenture was assessed according to one or more of the following specific criteria: repeated activation or replacement of the matrices, rocking of the overdenture, lack of stability in an anteroposterior direction, repeated adjustments to the contour of the intaglio surface, or complaints of increased food accumulation underneath the overdenture.

If any of these events occurred, the need for relining was verified with a wash impression on the intaglio surface of the overdenture using polyvinyl siloxane or irreversible hydrocolloid. If this impression had a thickness greater than 1 mm, a reline was deemed necessary and carried out using a polyether impression material (Impregum). The criteria for remaking overdentures were subject to clinical judgement but corresponded to similar criteria for replacing conventional complete dentures.[37]

The six-field table analysis for prosthodontic success was applied[35] at the 5-year time point. This was prior to the change of attachment system in the Steri-Oss group to the Locator attachment system. Allocation of each participant's implant overdenture was performed from a prosthodontic perspective to successful, surviving, unknown (lost to follow-up), deceased, retreatment (repair), and retreatment (replace) categories. Two-implant overdentures were considered successful if they had no retreatment except for accepted prosthodontic maintenance. Accepted prosthodontic maintenance was defined as a limit of either two replacements of patrices or matrices in the first year, five replacements in 5 years, or a reline of the overdenture in 5 years. The average longevity of different matrices was calculated by averaging the years between replacements of matrices. If accepted maintenance of the original overdenture was exceeded, it was then allocated to the retreatment (repair) category. If the implant overdenture was not serviceable and a replacement prosthesis


Fig 1 Different implant overdenture attachment systems.

Fig 1a *(left)* Brånemark 2.25-mm ball patrices (reprinted from Payne et al[24] with permission).

Fig 1b *(right)* Brånemark gold matrices (reprinted from Payne et al[24] with permission).


Fig 1c *(left)* Straumann 2.25-mm retentive anchor patrices (reprinted from Payne et al[31] with permission).

Fig 1d *(right)* **(top)** Straumann gold matrices and **(bottom)** Straumann titanium matrices with stainless steel springs (reprinted from Watson et al[15] with permission).


Fig 1e *(left)* Southern 3.95-mm ball patrices (reprinted from Watson et al[15] with permission).

Fig 1f *(right)* Southern plastic matrices (reprinted from Watson et al[15] with permission).


Fig 1g *(left)* Southern 2.25-mm ball patrices (reprinted from Payne et al[31] with permission).

Fig 1h *(right)* Southern gold/platinum matrices (reprinted from Payne et al[31] with permission).


Fig 1i *(left)* Steri-Oss ball patrices (reprinted from Tawse-Smith et al[22] with permission).

Fig 1j *(right)* Steri-Oss rubber matrices (reprinted from Watson et al[15] with permission).


Fig 1k *(left)* Locator abutments (reprinted from Ma et al[33] with permission).

Fig 1l *(right)* Locator inserts (reprinted from Ma et al[33] with permission).

Table 1 No. of Participants According to Loading Protocol and Different Matrix Systems

Matrix	Loading protocol			Total
	2-week	6-week	12-week	
Steri-Oss rubber	0	10	11	21
Southern plastic	0	10	12	22
Southern gold/ platinum	11*	0	0	11
Straumann gold	11*	4	2	17
Straumann titanium	0	5	4	9
Brånemark gold	10	0	0	10
Total	32	29	29	90†

*Not included in 8-year data (n = 68).
†Total number of participants in 6-year data.

Table 2 Combined Prosthodontic Maintenance Events for All Matrix Systems

Matrix	Mean	Standard deviation	Range of events per participant
Southern plastic*	8.7	4.2	0–19
Straumann gold†	12.8	8.2	2–35
Southern gold/ platinum	16.4	7.5	5–30
Brånemark gold	28.8	12.6	9–47
Straumann titanium	24.9	10.7	13–39
Steri-Oss rubber	32.2	14.5	6–59
Overall mean	19.7	13.6	0–59

*Significantly lower mean number of maintenance procedures when compared with Steri-Oss rubber ($P < .05$).
†Significantly lower mean number of maintenance procedures when compared with all groups ($P < .05$).

was indicated, then the two-implant overdenture was allocated to the retreatment (replace) category.

Results

Prior to implant loading with the overdentures (baseline), 5 participants failed to return, resulting in 101 participants examined at baseline. Progressive attrition of participants occurred with deaths, dropouts, and emigration, resulting in a total cohort of 90 participants being available for the 6-year recall (Table 1) and a total of 68 participants for the 8-year recall. There were time delays related to the extent of the clinical trial and subsequent implant surgeries with the Straumann and Southern 2-week loading groups (11 Straumann gold and 11 Southern gold/platinum matrices). This resulted, at the time of collection of this data, in these two groups being at their 6-year recall as opposed to the 8-year recall, which was done for all the 12-, 6-, and Brånemark 2-week loading groups. The mean age of the cohort followed after 8 years was 72.4 ± 8.0 years, with an age range of 49 to 93 years.

Combined Prosthodontic Maintenance Events

There were a total of 1,740 separate maintenance events necessary for the mandibular overdentures over 8 years (range: 131 to 300 per year). Throughout the study period, an annual mean number of 2.41 maintenance events were required per participant. The highest number of maintenance events over 8 years was recorded for the Steri-Oss/Locator group (32.2 ± 14.5), followed by the Brånemark group (28.8 ± 12.6). The Southern plastic matrices group had the lowest number over 8 years (8.7 ± 4.2), and when compared with all other groups, this was statistically significant ($P < .05$). There was a sharp drop off in the mean number of maintenance events from 5.4 ± 3.8 in year 5, which was the last year that the Steri-Oss rubber matrices were used, to 0.8 ± 1.5 events in year 6, after the same cohort of participants was transferred to the Locator attachment system. The range of maintenance events within each overdenture attachment system group was large, making meaningful comparison of the mean values difficult because of large standard deviations (Table 2).

The proportion of participants with one or more mandibular overdenture maintenance event was greatest during year 1 of service (73.3%) and least in year 6 of service (44.4%) (Fig 2). However, the overall frequency of maintenance events (n = 302) was greatest in year 2 of service. Of those participants requiring maintenance, the annual mean number of maintenance events per participant also peaked in year 2 (5.6 ± 4.3) and was lowest in year 8 (3.0 ± 1.3) (Table 3). When participants not requiring maintenance were included, the mean number of maintenance events per year peaked in year 1 (3.1 ± 3.1) and year 4 (3.3 ± 4.1) and was lowest in year 6 (1.5 ± 2.1) (Table 4).

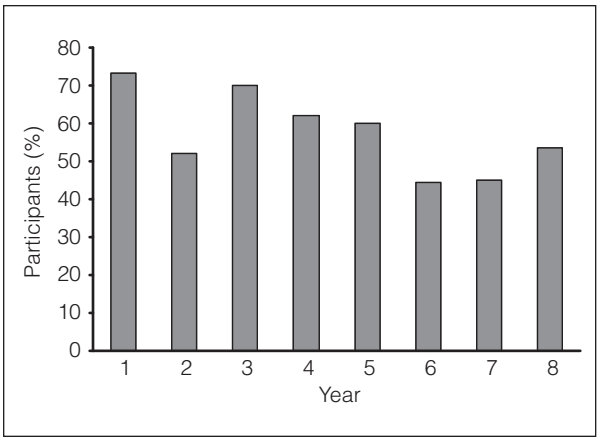

Fig 2 Percentage of participants with one or more prosthodontic maintenance event per year.

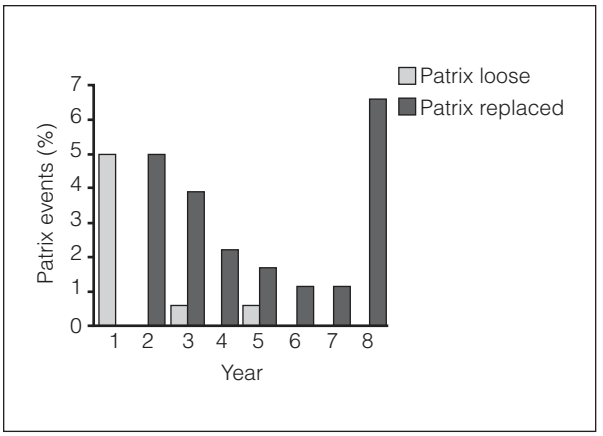

Fig 3 Percentage of patrix maintenance events across all systems over 8 years.

Table 3 Mean Annual No. of Maintenance Events per Participant Excluding Those that Did Not Require Prosthodontic Maintenance

Year	Mean no. of events	Standard deviation
1	4.2	2.9
2*	5.6	4.3
3	4.2	2.7
4†	5.3	4.0
5	3.9	2.9
6	3.4	1.9
7	3.6	2.1
8	3.0	1.3

*Significantly greater compared with years 6 and 8.
†Significantly greater compared with year 8.

Table 4 Mean Annual No. of Prosthodontic Maintenance Events per Participant Including Those that Did Not Require Maintenance

Year	Mean no. of events	Standard deviation
1*	3.1	3.1
2	2.9	4.2
3	2.9	3.0
4†	3.3	4.1
5	2.4	3.0
6	1.5	2.1
7	1.6	2.4
8	1.6	1.8

*Significantly greater compared with year 6.
†Significantly greater compared with years 6, 7, and 8.

Patrix-Specific Maintenance

The number of replacements of ball abutments or retentive anchors was low. The most common patrix events were replacement followed by loosening. The majority of loose patrices (n = 10) occurred within the first year of service. There were no incidents of patrix screw fracture. Of 180 patrices, a total of 39 (21.6%) required replacement over 8 years (Fig 3). Of the 12 replacements in year 8, 42% (n = 5) were from the Straumann titanium matrix group, and the remaining replacements were evenly distributed among the other groups.

Matrix-Specific Maintenance

The most common matrix maintenance event involved replacement (n = 793) followed by matrix activation (n = 412). Matrix replacement (n = 192) and activation (n = 148) of all systems peaked during year 4. The mean number of matrix activation and replacement events over 8 years identified distinct differences (Table 5). The mean time to replacement of matrices was calculated, and a longevity ranking of the matrices was formulated (Table 6). Over the 6-year period, the matrices with the shortest longevity were Steri-Oss rubber at 1.4 ± 0.7 years, and those with the best longevity were Straumann gold at 3.9 ± 2.1 years. Straumann gold matrices lasted significantly longer than all other matrices ($P < .05$). Southern gold/platinum, Brånemark gold,

Table 5 Mean No. of Matrix Activation and Replacement Events Over 8 Years

	Activate		Replace	
Matrix	Mean	Standard deviation	Mean	Standard deviation
Brånemark gold	18.0	19.8	5.5	7.7
Southern gold/ platinum	11.9	11.8	2.2	4.4
Straumann gold	9.6	13.5	1.1	3.2
Straumann titanium*	0	0	13.7	14.7
Southern plastic*	0	0	4.3	7.6
Steri-Oss rubber*	0	0	29.2	24.3
Mean	5.3	12.1	10.3	18.2

*Not possible to activate, only replace.

Table 6 Mean Time to Replacement of Different Matrices Over 6 Years

Matrix	Mean (y)	Standard deviation
Straumann gold	3.9*	2.1
Southern gold/platinum	3.1†	1.7
Brånemark gold	2.7‡	1.5
Southern plastic	2.5§	1.4
Straumann titanium	1.7	0.8
Steri-Oss rubber	1.4	0.7

*Lasted significantly longer than all other matrices.
†Lasted significantly longer than Steri-Oss rubber and Straumann titanium matrices.
‡Lasted significantly longer than Straumann titanium and Steri-Oss rubber matrices.
§Lasted significantly longer than Steri-Oss rubber matrices and Straumann titanium matrices.

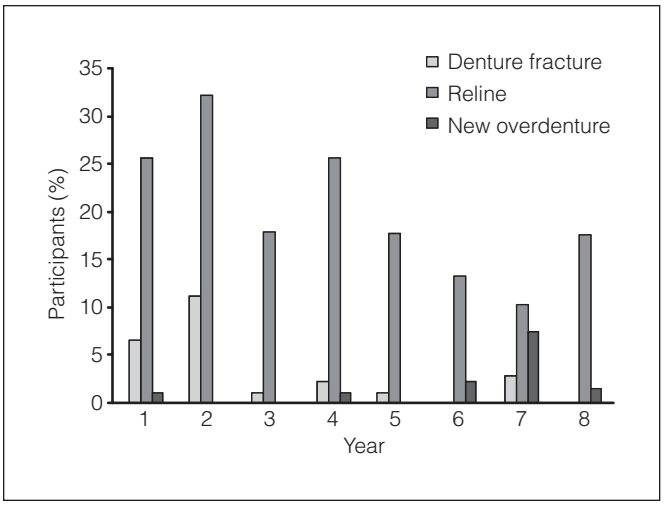

Fig 4 Percentage of participants requiring overdenture events across all groups to year 8.

and Southern plastic matrices all lasted significantly longer than the Straumann titanium and Steri-Oss matrices ($P < .05$).

Maintenance Events Related to Loading Protocol

There were no significant differences in the overall maintenance requirements found between the 2-, 6-, and 12-week loading groups over 6 years ($P > .89$). There were also no significant differences between mean overall maintenance and loading protocol. It is relevant that although there was a significant difference between loading protocols at the end of year 6 ($P < .05$), this was attributed greatly to reduced maintenance requirements of the Steri-Oss group after changing to the Locator attachment system.

Overdenture-Specific Maintenance

Relines were the most common maintenance procedure specific to the mandibular overdentures (Fig 4). Although the relines peaked during year 2 across all groups regardless of attachment system (n = 29), the mean time to reline was 3.37 ± 2.06 years. After 8 years, the 68 participants followed had needed 117 overdenture relines. There were no significant differences in the actual number of relines required between the different loading protocols and the attachment systems used. Remaking of overdentures with their opposing complete maxillary dentures peaked by year 7, with a mean time to remake of 5.81 ± 2.04 years. During the entire clinical trial, 10 new overdentures were fabricated, and of these, 50% were made at year 7.

Table 7 Prosthodontic Success at Year 5: Six-Field Table Analysis[34]

	Brånemark gold	Straumann gold	Straumann titanium	Southern plastic	Southern gold/ platinum	Steri-Oss rubber
No. of patients	10	24	12	24	12	24
Success	4 (40%)	13 (54%)	4 (33%)	15 (62.5%)	6 (50%)	6 (25%)
Surviving						
Deceased	0	1	0	1	1	0
Unknown	0	3	1	2	1	1
Retreatment (repair)	5	6	6	6	4	17
Retreatment (replace)	1	1	1	0	0	0

Prosthodontic Success

The six-field table analysis revealed the levels of prosthodontic success for the different matrices over a 5-year period, which were: 62.5% for Southern plastic, 50% for Southern gold/platinum, 54% for Straumann gold, 40% for Brånemark, 33% for Straumann titanium, and 25% for Steri-Oss rubber (Table 7).

Discussion

The nature of this ongoing clinical trial and the difficulty in minimizing confounding variables within a patient cohort were profound. Therefore, any conclusions must take into consideration the size of the cohort, and any extrapolations to private practice should carry a degree of caution. The authors acknowledge that there are limitations with this research, specifically related to time delays for initial surgical operations for the Straumann and Southern 2-week loading protocol groups. More data on these groups up to year 8 could have influenced the final recommendations. However, the authors propose that the prosthodontic maintenance trends were already established by year 6.

The initial aim of this research was to determine the influence of varying loading protocols on prosthodontic maintenance beyond 5 years. No significant differences were found between the loading protocols and the attachment systems used when it comes to the actual number of relines, or the number of dentures to be remade. Some short-term studies indicate that prosthodontic maintenance may increase in early and immediate loading protocols (because of more early relines) when compared with conventional loading protocols.[30,38–40] This research found no statistically significant differences between the 2-, 6-, and 12-week loading groups. If a difference did exist between loading protocols, it would most likely be expected within the first year of service, with the early 2-week loading protocols possibly requiring more prosthodontic maintenance because of the mucosal swelling and the amount of healing at the time of loading. Unfortunately, the opportunity to detect more initial maintenance in the early loading groups was reduced because of the high levels of maintenance required with the Steri-Oss rubber matrices.

Although there was no significant difference between loading protocols and prosthodontic maintenance requirements, there were some clinical problems with estimating ball abutment heights within the 2-week loading groups. Often, the ball abutment heights selected would be slightly higher than normal to accommodate inflamed and swollen mucosa at or shortly after surgery.[24] After the healing period, recession left the ball abutment higher than usual, increasing the chances of overdenture puncture fractures and the need for an earlier reline. Commercial funding by way of component delivery matching patient treatment appointments restricted abutment selection.

The Toronto research group's[38,39] experience with an immediate loading protocol revealed higher maintenance and total costs. All participants in their immediate loading group required more prosthodontic maintenance, which comprised overdenture remakes and laboratory relining of prostheses. A total of 74% of participants in the immediate loading group needed a reline to improve the denture seal around the bar housing. No difference was observed in the time costs associated with the two protocols, and the immediate loading protocol was not cheaper than a conventional protocol. The prosthodontic maintenance encountered in the immediate loading group did not negate the clinical potential of the treatment,

but rather suggested that the protocol may benefit from modification. By comparison, the current results did not find an increased burden of prosthodontic relines with the 2- and 6-week early loading protocol groups. This evidence, together with sound surgical outcomes,[33] supports early loading at 2 weeks as opposed to an immediate loading protocol.

Other classic research from the same Toronto group[8] found similar prosthodontic maintenance, but on average, the longevity of overdenture prostheses was longer (approximately 12.47 years for replacement of dentures) and indirect relining was necessary every 4.41 years. The authors' explanation for the difference in the time frames for the current research compared to that of the Toronto group is that a higher number of cohorts, as well as the ease with which participants were able to attend the research center in a much smaller city, revealed a more accurate time to relines and remakes. The authors found subjectively noticeable requests from participants for prosthodontic maintenance at the time of annual recalls.

The secondary aim of this research was to evaluate the prosthodontic maintenance of six different attachment systems on unsplinted mandibular implants. First, although not identified frequently as implant success by researchers, the overall prosthodontic success should be critical, bearing in mind the profound patient implications that the prosthodontist has to deal with. As far as the authors are aware, there is only one other randomized controlled trial[36] that is comparable to the current study. The Vancouver research team,[36] using the same criteria as the six-field protocol for implant overdenture outcomes, showed that a two-implant bar-clip mandibular overdenture was a significantly more successful prosthesis requiring less maintenance than those with Brånemark titanium matrices and spring ball attachment overdentures. It could be argued that the use of individual prosthodontic maintenance events does not always accurately reflect the postinsertion care required for a given prosthesis. Some maintenance events are easily solved, for example, activation of a matrix to improve lost retention. However, a reline or replacement of the Southern plastic matrices in the current research was more involved because of the indirect procedure and an extra chairside visit to deliver the prosthesis.

In contrast to other short- and long-term studies, patrix maintenance requirements in the current cohort were low. Some much earlier research found excessively high levels of patrix maintenance, primarily involving screw loosening in two-piece ball attachments where the ball attaches to an abutment via a prosthetic screw.[17,41,42] Comparatively less maintenance was necessary in this research compared with earlier studies, most likely because of improvements in abutment screw mechanics and design. Ball abutments used in this research were both one- and two-piece, and the appropriate torque advised by the manufacturer was always applied.

There are indications that results from the current research related to matrix maintenance requirements are consistent with earlier studies, albeit that these earlier studies used a conventional loading protocol.[18,36,41,43–45] A long-term investigation of two-implant overdentures, using ball or bar attachments, demonstrated a mean longevity of the first prosthesis to be 12.47 ± 3.94 years.[8] Of those participants that required replacement of their two-implant overdentures, the average time to first replacement was 5.8 ± 2.0 years. Standard deviations in this study and others[8,44] were large, reflecting the wide variation that can occur in clinical research, despite attempts at controlling as many variables as possible. There is also evidence that the frequency of technical complications/repairs per patient was higher around bar than ball attachments during the 5-year observation period.[41]

Results of some studies are at odds with much of the literature regarding splinted and unsplinted mandibular overdentures, but this may occur because of study design. One study, for example, may not have closely monitored its cohort of participants over the 8-year period with regard to the frequency of prosthodontic maintenance events.[45] In this study, there was also no analysis of the number of matrix activations that were required within the study period, although it was reported that 50% of participants required no further treatment after insertion of the original prosthesis. In contrast, a previously mentioned randomized controlled trial reported that 73% of mandibular two-implant overdentures required matrix activations, 17% required tightening of patrix screws, and 5% required replacement of matrices over 3 years.[36]

There is undoubtedly debate regarding data related to prosthodontic maintenance predications between researchers.[46] It has been proposed that other established research teams[45] performed an aftercare and cost effectiveness assessment of three types of implant-retained mandibular overdentures in a cohort of 110 patients with a follow-up of 8 years. They claimed that their observations were unique, but there are other studies on aftercare and costs of mandibular overdentures in large groups of patients with a comparable or longer follow-up. It has been argued by others[46] that they[45] omitted comparing their outcomes with those studies. In consideration of overall treatment time needed for aftercare, and thus

costs, it was proposed that there might be a pitfall. It was proposed that from approximately 8 years after implant loading, there could be an increased need for mandibular implant overdenture remakes. Thus, these researchers[45] could have underreported the need for mandibular implant overdenture remakes. In response, Stoker and colleagues[45,46] stated that an evaluation period is almost always too short to reveal every possible aftercare event during the lifecycle of a chosen treatment modality, arguing that long-term evaluations in randomized clinical trials of mandibular implant overdentures are still scarce. At that time, there was no specific proof that there is an increased demand for mandibular overdenture remakes 8 years after loading, or even after 10 years. The authors believe the research in this paper now provides the evidence toward this.

Significant maintenance of the majority of splinted and unsplinted mandibular two-implant overdentures was also required in another long-term, randomized controlled trial.[17] Thirty-six completely edentulous patients had two Brånemark implants placed in the mandible and were randomly allocated into three groups of different attachment systems: bars, magnets, or balls. In the ball group, the need for tightening of abutment screws was the most common mechanical complication, whereas in the magnet and bar groups, the most common complications were wear and corrosion and the need for clip activation, respectively. Also of note is the comparison to strong evidence in the hierarchy of research methodology in a crossover clinical trial.[18] A total of 18 edentulous participants received two mandibular implants, and a new overdenture with magnet, ball-socket, or bar-clip attachments was applied in random order. At the end of the research, the attachment type of choice was fitted in the overdenture. After 10 years, a total of 14 subjects with a ball-socket or bar-clip attachment were evaluated to show no marked difference in satisfaction between the two attachment systems.

Previous reports of excessive maintenance problems for Straumann titanium matrices[15,36] were also confirmed in the current research findings. These authors attributed excessive wear of the patrices to the stainless steel springs encased within the matrix housings. In the current research, the number of patrix replacements for the Straumann titanium group was significantly greater than other groups in year 4 ($P < .002$). In all other years, the number of patrix replacements was greatest in the Straumann titanium group. Previous reports of excessive maintenance of the Straumann titanium matrix at 1 year[15] and the Nobel Biocare version of the Straumann titanium matrix over 3 years[36] were confirmed in this study. The Vancouver researchers[36] reported that only 29% of participants within the Nobel Biocare titanium matrix group were allocated to the success field over 3 years. The current research found a similarly low success rate of 33% over 5 years. The authors now condemn this titanium matrix design by virtue of excessive maintenance procedures and long-term wear of the stainless steel spring against the titanium ball abutment and recommend its withdrawal from the commercial market.

The design of any particular matrix must be taken into account when comparing the type of maintenance that occurs. For example, the Straumann and Brånemark gold matrices required significantly more activations than the Southern plastic matrices. However, the Southern plastic matrices could not be activated, and relines were carried out if more retention was required. Activation of the Dalla Bona–type matrices is a procedure that requires minimal chair time. Participants within the Southern plastic group often presented requesting more retention when the mandibular overdenture required a simultaneous reline according to the outlined criteria. This was verified by the fact that there was no statistical significance between any of the matrix systems and the number of relines required over the 8-year period. This suggests that the majority of the Southern plastic matrices tended to have sufficient longevity to require replacement only when a reline was required. The Southern plastic matrices were the least resilient, allowing minimal rotation or stress release around the rotational axis of the implants. Despite contravening the axis of rotation theory that has been advocated within the literature,[47] the mandibular two-implant overdentures using Southern plastic matrices in the current study had the lowest number of prosthodontic maintenance events compared with all other matrices.

Although the authors acknowledge that the Steri-Oss attachment system is now obsolete, it is still most worthy of documentation. The results of the maintenance burden revealed with time that attachment system components for implant overdentures do require long-term clinical research, validating their use prior to widespread clinical use. Unfortunately, there are many other examples of implant hardware that have been tested on patients prior to adequate clinical research to prove their efficacy. These results clearly demonstrate that, like any other medical devices, implant components need long-term clinical research validating their use. The consequences of a poorly designed attachment system are generally not catastrophic. However, it is difficult to envisage that patients can be informed adequately of possible prosthodontic maintenance and expected costs of

this treatment option prior to commencing treatment. Unfortunately, the manufactured release and sale of some implant components that have not been subject to randomized controlled trials with well-described long-term treatment outcomes continue unabated. The proliferation and demands of commercial dentistry have ignored the lack of evidence in relation to overdenture attachment systems. The evolution from two-piece to one-piece ball abutments by commercial dentistry without rationale for change as well as the development of elliptical gold matrices over traditional Dalla Bona types are other examples. Finally, the acceptance of the Locator attachment system by multiple reputable gold standard implant systems may also be questioned in view of possible maintenance and complications over time.[48]

In concluding and interpreting the validity of this research, revisiting classic edentulous texts is appropriate to determine how long conventional complete dentures actually last and the timing of reline procedures to prolong their life or replace them.[49] If the longevity of implant overdentures is longer than conventional dentures, the support for the intervention is substantiated. However, if the longevity of the implant overdentures is shorter than conventional dentures, compounded by matrix maintenance and the implications of abbreviated protocols, especially immediate loading protocols, then this must be explained to the patient in terms of the evidence-based improvement of masticatory function leading to increased denture tooth wear.[50]

Conclusions

There are significant short- and long-term maintenance requirements that patients must be aware of before selecting mandibular two-implant overdentures as a treatment option. Early loading protocols do not influence long-term prosthodontic maintenance requirements of unsplinted two-implant overdentures. By contrast, attachment systems do influence prosthodontic maintenance, particularly with regard to the type of matrices used.

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