Patients' Evaluation of Two Occlusal Schemes for Implant Overdentures

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ABSTRACT

Background: There is an absence of conclusive evidence for occlusal schemes in implant overdentures.

Purpose: To investigate the consequences of two different occlusal schemes on levels of satisfaction for patients wearing implant overdentures.

Materials and Methods: Within an existing randomized controlled clinical trial, a physiologic occlusal scheme was compared with a lingualized occlusal scheme for 18 selected participants all with implant overdentures. Nine participants had conventional maxillary complete dentures opposing mandibular 2-implant overdentures; a further nine participants had maxillary 3-implant overdentures opposing mandibular 2-implant overdentures. All participants recruited had been wearing their original prostheses for 3 years with a bilateral balance occlusal scheme. The participants' existing satisfaction levels, as a baseline, were determined using visual analogue scale questionnaires. They were followed by similar assessments of two further occlusal schemes using 2-month assessment periods. On completion of the study, the participants selected their preferred occlusal scheme and semiformal interviews were conducted to assess the rationale for their choices.

Results: Baseline data showed all the participants had pre-existing high satisfaction levels. Thereafter, of those participants that received lingualized occlusion first, 55.6% reported that the physiologic occlusion was better than lingualized occlusion. For those participants who received the physiologic occlusion first, 85.7% reported that physiologic occlusion was better than lingualized occlusion. On completion of the study, 64.7% of the participants preferred the physiologic occlusion, 35.3% preferred the lingualized occlusion. However, when the two groups' satisfaction scores were modeled using the three main key indicator questions (general satisfaction, general ability to chew, or general function), there were no significant differences between them.

Conclusions: Within the limitations of a small number of participants, the majority of them still indicated a preference for a physiologic occlusion for implant overdentures. Improved function was given as the main indicator for that preference. Having implant overdentures in one or both jaws is not a formative factor in patient's opinions on occlusal schemes.

KEY WORDS: implant overdentures, occlusion, patient satisfaction

INTRODUCTION

Currently, the occlusal philosophies that are proposed for implant overdentures are based on those for conventional complete dentures.[1,2] A review of the literature highlights a lack of well-conducted randomized controlled clinical trials in the field of conventional complete denture and implant overdenture occlusion.[1–9] The Cochrane Collaboration review of clinical trials that compared complete dentures produced with different

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This research was presented at the 45th annual meeting of the Australian/New Zealand Division of the International Association for Dental Research, 25–28 September 2005, in Queenstown, New Zealand.

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DOI 10.1111/j.1708-8208.2007.00070.x

occlusal schemes highlighted that currently there was only one well-conducted clinical trial in this area.[6] Although there has been substantial research carried out on patient outcomes with implant overdentures, there is a paucity of evidence-based research on the effect of different occlusal schemes for patients already wearing implant overdentures.[4,8,10–17]

In the absence of an occlusal philosophy for implant overdentures, recommendations have therefore been made based on various implied criteria. Chapman[7] recommended bilateral balanced occlusion for mandibular implant overdentures only, and canine-guided occlusion for maxillary and mandibular implant overdentures. Wismeijer and colleagues[15] proposed that a lingualized occlusion concept be adopted when conventional maxillary dentures oppose 2-implant mandibular overdentures. They based their occlusal concept choice on the fact that the opposing antagonistic arch condition influenced the choice of occlusal concept, as well as the need for the implants to be vertically loaded with horizontal forces best avoided. Regrettably these recommendations were postulated in the absence of any clinical research findings specifically comparing occlusal schemes. Conversely, Mericske-Stern and colleagues[18] promoted a balanced occlusion because it was seen by them to deliver even distribution of load between implants and the mucosa, and provided stability during function. However, these authors still concluded, that in implant prosthodontics, a specific evidence-based occlusion philosophy has not yet been developed.[18] More recently, Kim and colleagues[2] emphasized the importance of implant occlusion for implant longevity using a biomechanical rationale. They too recommended that lingualized occlusion was the standard occlusal scheme to be used for implant overdentures, with a monoplane occlusion being indicated for patients with severe residual ridge resorption. It was again emphasized that there were currently no evidence-based, implant-specific concepts of occlusion, and future clinical studies in this area were encouraged.

A study by Khamis and colleagues[8] highlighted that the occlusal anatomy of the teeth directly impacted on chewing efficiency. Their study considered the effects of three different occlusal forms (zero-degree teeth, 30-degree teeth, and lingualized occlusion) on the denture-bearing tissues, and masticatory efficiency, in participants with mandibular implant overdentures. The zero-degree occlusal form had a significantly higher number of chewing strokes than the 30-degree or lingualized occlusal forms. The authors reasoned that, like natural teeth and unlike conventional dentures, the occlusal anatomy (in terms of cusp angle) of the teeth directly impacted on chewing efficiency. With this in mind, they also concluded that the choice of implant overdenture occlusion should not be based on conventional denture principles. Following the development of the original concept of lingualized occlusion in the late 1920s, various modifications eventually resulted in Lang and Razzoog[1] defining lingualized occlusion as one that is in fact balanced, but with the occlusal contacts being between the maxillary palatal cusps of the posterior teeth and modified mandibular teeth. The palatal cusps of the maxillary teeth are in continuous contact with the fossae and inclines of the mandibular teeth during eccentric movements of the mandible. The lingualized occlusal scheme allows for freedom in centric relation, and even contact during lateral and protrusive movements.

Physiologic occlusion has been defined in the *Glossary of Prosthodontic Terms* (since 1977), with the current definition being "occlusion in harmony with the functions of the masticatory system."[19] A physiologic occlusion focuses on the importance of locating the mandible in a centric position that is based on swallowing and habitual closing. Another occlusal requirement is that there must be no premature contacts during lateral and protrusive movements. The concept relies on the neuromuscular system to aid pathological, tooth-guided movements of the mandible. The mandible is brought into a physiologic centric occlusion with even and simultaneous contact.[20–22]

The aim of this research was to evaluate levels of patient satisfaction with a physiologic occlusal arrangement and a lingualized occlusal arrangement when wearing implant overdentures. The two occlusions compared were selected because they are distinctly different; lingualized occlusion being a proven occlusal scheme for conventional complete dentures that has been adopted for use in implant overdentures; physiologic occlusion being based on natural teeth, which relies on the neuromuscular system.

Therefore the hypothesis to be evaluated by this research was that there would be no difference in the levels of patient satisfaction with a physiologic occlusal arrangement and a lingualized occlusal arrangement of the denture teeth when wearing implant overdentures.

MATERIALS AND METHODS

Study Design

Following local ethical approval from the University of Otago, Dunedin, New Zealand (departmental level; category B), a total of 18 edentulous participants (age range 55–80 years; mean age 67; 38% male; 62% female) were selected as follows:

Group 1: with nine participants having an existing conventional maxillary complete denture with an opposing mandibular 2-implant overdenture.

Group 2: with nine participants having an existing maxillary 3-implant overdenture with an opposing mandibular 2-implant overdenture.

Inclusion criteria were that participants had to have been wearing a mandibular 2-implant overdenture for at least 3 years. The mandibular 2-implant overdenture had to be obtaining adequate support, stability, and retention from its patrices and matrices, regardless of either the implant or attachment system. Exclusion criteria were any "first-time" implant overdenture patients or those with worn or fractured patrices or matrices in their 3-year-old mandibular 2-implant overdenture. The posterior denture teeth all showed signs of occlusal wear following the previous 3 years of service. All had a bilateral balance occlusal scheme (established with Orthosit PE denture teeth; Ivoclar Vivadent AG, Schaan, Liechtenstein).

This research had two sequential clinical interventions, which consisted of changing each of the participants' occlusal schemes from one occlusal scheme to another. Group 1 had two new sets of prostheses fabricated, each representing a different occlusal scheme. In Group 2, the participants' pre-existing denture bases were used and only the posterior denture teeth were replaced, initially to change them to the first occlusal scheme. The reason for not fabricating new overdentures for Group 2 was to avoid interference with a simultaneous ongoing randomized controlled clinical trial that Group 2 participants were also included in. However, while the two groups had slightly different fabrication techniques applied, specific care was taken not to alter the position or shape of the maxillary anterior teeth and/or the fit of the dentures. Standard post-insertion appointments were performed.

Patient Questionnaires and Data Collection

Prior to evaluating a new occlusal scheme, the current satisfaction levels of each participant with his/her existing prostheses were measured. This established baseline data served as a basis for comparison with future satisfaction levels. The new occlusal schemes were randomly allocated to the participants using a sealed envelope approach. Therefore, participants were first allocated either a physiologic or a lingualized occlusal arrangement. The participants assessed this first occlusal scheme for a period of 2 months, after which the occlusal schemes were changed. This period of 2 months was in accordance with the recommended periods of adaptation to new dentures for patients in a previous clinical trial.[23]

Visual analogue scale (VAS) questionnaires (as a quantitative assessment) were used to measure participants' satisfaction levels. Each VAS consisted of a 100-mm horizontal line upon which participants drew a vertical line through to record their response to set questions. The questionnaire used was a modified version of one supplied by research collaborators from McGill University, Montreal, Canada (Table 1). To confirm that the questionnaire's clarity and ease of use had not been compromised, three pilot patients who were not participants in the study vetted the questionnaire. The study participants answered all questions independently of the researcher. The questionnaire had sections covering ease of cleaning, general satisfaction, ability to speak, comfort, appearance, stability, ability to chew, function, and general satisfaction. The main outcome measures to be determined were general satisfaction, general ability to chew, and general function. Following the evaluation of both of the occlusal schemes by each participant, a final semi-structured interview (as a qualitative assessment) was conducted to assess the rationale for participants' preferred occlusal arrangement for posterior denture teeth. Subsequent to each answer being recorded, the response was read back to the participant for confirmation and further clarification. This included addressing the adaptive or maladaptive nature[24] of the participant to removable prostheses.

Prosthodontic Procedures

The prostheses for the participants were all fabricated using conventional techniques.[24,25] For all the participants in Group 1, the preliminary and definitive casts were poured following standardized preliminary and

TABLE 1 Questions Asked in Final Questionnaire*

General satisfaction
1. Ease of cleaning
How difficult is it to clean your dentures and mouth?
2. General satisfaction
In general, are you satisfied with your dentures?
3. Ability to speak
How difficult is it for you to speak because of your dentures?
4. Comfort
Are you satisfied with the comfort of your dentures?
5. Appearance
Are you satisfied with the appearance of your dentures?
6. Stability
Are you satisfied with the stability of your dentures?
7. Oral condition
In general, are you satisfied with the health of your mouth?
8. Ability to chew
In general, do you find it difficult to chew food with your dentures?
How difficult is it for you to eat fresh white bread with your dentures?
How difficult is it for you to eat **hard cheese** with your dentures?
How difficult is it for you to eat **raw carrots** with your dentures?
How difficult is it for you to eat **sliced cold meat** with your dentures?
How difficult is it for you to eat **sliced steak** with your dentures?
How difficult is it for you to eat **raw apples** with your dentures?
How difficult is it for you to eat **lettuce** with your dentures?
9. Function
In general, is your food well chewed before swallowing?
Are pieces of **fresh white bread** well chewed before swallowing?
Are pieces of **hard cheese** well chewed before swallowing?
Are pieces of **raw carrot** well chewed before swallowing?
Are pieces of **sliced cold meat** well chewed before swallowing?
Are pieces of **sliced steak** well chewed before swallowing?
Are pieces of **raw apple** well chewed before swallowing?
Are pieces of **lettuce** well chewed before swallowing?
Additional questions that did not use the visual analogue scale (VAS) and required a written answer
In general, how did you adapt to your new dentures?
Compared to your old set of dentures was this set of dentures "Better/Same or Worse" at chewing food in general? Why?
Which set of dentures do you want to retain?

*This table reflects the question only and the format presented to the participants allowed for the VAS scale and spaces for comments (adapted from original questionnaires from McGill University, Montreal, Canada).

final impression procedures. A silicone duplication system was used to make duplicates of the secondary casts, for the purpose of making the second set of dentures. The horizontal and vertical jaw relations were then registered with impression copings incorporated into a light-cured base. This was mounted (using the split-cast technique) into a Twin Hoby articulator (Shioda Dental Mfg. Corporation, Minami-Nasumachi, Nasu-gun, Tochigi, Japan) using average setting (sagittal condylar path inclination 25°, Bennett angle 15°, anterior inclination 20°, lateral wing 10°) and using the philosophy of Bonwill's triangle.[26–28]

The participants alternately received both a lingualized and a physiologic occlusion for assessment in the 2-month assessment periods. The lingualized occlusions were arranged with SR Ortholingual DCL denture teeth (Ivoclar Vivadent AG). The occlusal surfaces of the Ortholingual DCL teeth are specifically designed for the lingualized occlusal scheme. The maxillary teeth have pronounced palatal cusps to enable a precisely defined lingualized centric occlusion. The occlusal contacts were located on the maxillary lingual cusps of the posterior teeth and on the central fossae of the modified mandibular teeth. The modified mandibular teeth had flattened buccal cusps, and a U-shape was present on the occlusal table. A balanced occlusion was achieved by placing the palatal cusps of the maxillary teeth in contact with the mandibular teeth in a way that allowed for continuous contact during eccentric movements of the mandible. The physiologic occlusions were arranged with Vita Physiodens denture teeth (Vita Zahnfabrik, Bad Säckingen, Germany). The premolars and molars are based on the average size of the healthy dentition of adults aged 21 years and over. The concept relies on tooth-guided movements being considered to be pathological, and ultimately guided by the neuromuscular system. The mandible is brought into a physiologic centric with homogeneous and simultaneous contact. The average number of contact points is 10 per posterior quadrant (ranging from 6 to 14 contacts per quadrant), and five contacts per quadrant in the anterior area. The physiologic centric relation provides point centric contacts with freedom in centric. The posterior occlusal contacts were situated on the inner slopes of the non-working cusps, which are in contact with the outer slopes of the working cusps.[21,29]

Wax try-in of the prostheses was done and silicone matrices (keyed onto the cast) were made of the final

trial tooth arrangements prior to processing. The dentures were processed using Vertex™ Rapid Simplified denture acrylic (Vita Zahnfabrik). After processing, the dentures were remounted, and processing errors were removed by selective occlusal grinding. Special care was taken at this point to ensure that the occlusal contacts were consistent with the specific occlusal philosophy. The prostheses were then trimmed, polished, and delivered to each participant.

For all participants in Group 1, the second set of dentures was constructed using the duplicate casts and articulation. The existing anterior and posterior teeth locations were duplicated using silicone matrices. Care was taken not to change the appearance and position of the anterior teeth; placing the new anterior teeth into each matrix and pouring molten wax around them to re-establish the identical position and contour achieved this. The posterior teeth were then placed individually according to the position of the previous teeth, but in the new occlusal arrangement.

For all participants in Group 2, the maxillary 3-implant overdentures intaglio surfaces remained unchanged, while their opposing mandibular 2-implant overdentures were relined. Following articulation, only the maxillary posterior denture teeth were removed, hence leaving the intaglio surface of the prosthesis intact. The remaining mandibular teeth were used as a guide for placement of the new maxillary posterior teeth, after which the mandibular teeth were replaced using the maxillary teeth as a guide. Following wax contouring of the maxillary denture, auto-polymerizing Vertex Castapress acrylic material (Vita Zahnfabrik) was used to fix the posterior teeth to the existing base using a silicone matrix to locate the teeth. These mandibular implant overdentures had to be relined, so this was done at the same time as the incorporation of the first arrangement of new posterior teeth. When placing the second occlusal scheme into the dentures for Group 2, it was not necessary to reline the mandibular implant overdenture, meaning that the technique that was used for the maxillary denture (described earlier) was also used for the mandibular implant overdenture.

Data Analysis

The data were analyzed using the statistical programs SPSS (Statistical Package for the Social Sciences, version 13.0, SPSS Inc., Chicago, IL, USA) and Stata (version 8, Stata Corporation, College Station, TX, USA).

First, the baseline means and standard deviations were computed. Using paired *t*-tests, the baseline mean values for each item were compared with the mean values from after the first occlusion. The second occlusion was also compared with the mean values of the baseline, and then the mean values of the first occlusion were compared to the mean values for the second occlusion. There was one withdrawal from the study from a participant in Group 1, who received the first occlusion, but did not participate further. The reason for withdrawal was ill health of the participant and inability to attend the additional clinical sessions. That person's initial data are represented in the mean values presented in the results tables, but these data are not included in the subsequent comparative analysis or the final preference percentages. This was done because the withdrawal from the study was due to external factors rather than their occlusion.

Differences between groups' mean values were tested for statistical significance using Mann-Whitney U-tests because of (1) the non-Gaussian distribution of data and (2) the inequality of variance among the groups. Differences in proportions were tested for statistical significance using the chi-square test. For all tests, the α value was set at 0.05.

The crossover design of the study required the use of the general linear model in Stata. This enabled detection of (and controlling for) any period effect, period-by-treatment interaction, carry-over, or patient-by-period interaction.[30]

RESULTS

Participant Preferences

The following quantitative results show participant preference at particular points during the study. Initial preferences prior to receiving the second occlusion showed that, of the participants who received lingualized occlusion first, 87.5% reported that lingualized occlusion was better than their old dentures, while 12.5% reported that it was worse. Of those who received the physiologic occlusion first, 60% reported that physiologic occlusion was better than their old dentures, with 20% reporting it to be the same and 20.0% reporting it to be worse.

Following the second assessment period, the first and second occlusions were compared. Of those who received lingualized occlusion first, 33.3% reported that lingualized occlusion was better, with 11.1% reporting it

TABLE 2 Mean Baseline Satisfaction Scores by Implant Group of Existing Prostheses with a Worn Bilateral Balance Occlusal Scheme (SD in Brackets)†

	Group 1 Mandibular implants only ($n = 9$)	Group 2 Maxillary and mandibular implants ($n = 9$)	Combined groups ($n = 18$)
Overall acceptance of dentures			
General satisfaction‡	78.2 (17.0)	66.8 (35.3)	72.5 (27.5)
Ease of cleaning	68.1 (30.9)	65.7 (24.3)	66.9 (27.0)
Ability to speak	82.4 (19.6)	89.7 (5.7)	86.1 (14.5)
Comfort	78.5 (21.1)	73.2 (28.7)	75.8 (24.6)
Appearance	79.4 (24.1)	75.4 (30.6)	77.4 (26.8)
Stability	71.2 (29.4)	63.6 (29.3)	67.4 (28.7)
Oral condition, general	76.7 (27.3)	81.8 (16.0)	79.3 (21.9)
Ability of dentures to chew various food types			
Ability to chew, general‡	80.6 (21.3)	76.7 (16.4)*1	78.8 (18.7)*1
Ability to chew, fresh white bread	73.1 (25.7)*1	80.0 (19.0)*2	76.3 (22.3)*3
Ability to chew, hard cheese	80.7 (14.7)*1	84.8 (10.7)*1	82.8 (12.6)*2
Ability to chew, raw carrots	77.3 (21.2)*1	76.7 (24.6)	77.0 (22.4)*1
Ability to chew, sliced cold meat	80.7 (20.6)	82.2 (16.8)	81.5 (18.2)
Ability to chew, sliced steak	76.4 (28.2)	77.2 (25.1)	76.8 (25.9)
Ability to chew, raw apples	71.1 (28.4)	85.8 (9.2)	78.5 (21.8)
Ability to chew, lettuce	72.0 (28.8)	80.7 (12.2)	76.4 (21.9)
Function of dentures in relation to various food types			
Function, general‡	72.2 (28.6)	79.8 (11.3)	76.0 (21.5)
Function, fresh white bread	74.1 (19.7)*1	71.5 (19.7)*2	72.9 (19.0)*3
Function, hard cheese	73.7 (18.4)	71.6 (24.2)*1	72.7 (20.7)*1
Function, raw carrots	73.3 (20.5)*1	72.4 (23.6)	72.8 (21.5)*1
Function, sliced cold meat	72.0 (26.0)	73.0 (23.6)	72.5 (24.1)
Function, sliced steak	71.8 (25.9)	72.3 (22.7)	72.1 (23.6)
Function, raw apples	68.1 (29.2)	76.3 (22.0)	72.2 (25.4)
Function, lettuce	72.3 (25.3)*1	72.8 (21.0)	72.6 (22.3)*1

*Indicates the number of nonresponses for question.
†The score is based on a satisfaction scale (visual analogue scale) from 0 to 100, with a higher number indicating a higher satisfaction.
‡Key indicator questions.

to be the same, and 55.6% reporting it to be worse. Of those who received the physiologic occlusion first, 85.7% reported that it was better than the lingualized occlusion, with 14.3% reporting it to be the same. After experiencing both schemes, 64.7% of the participants preferred the physiologic occlusion with lingualized occlusion preferred by the remainder.

Baseline data from the VAS questionnaire are presented in Table 2. These data related to the participants' original prostheses, which had been set up using bilateral balance occlusal scheme. There were already high satisfaction levels with the baseline prostheses, with no statistically significant differences between the groups for any of the key indicator items. There were some minor differences in means; for example, Group 2 reported a higher ability to chew raw apples and lettuce than Group 1 (14.7 and 8.7, respectively). There was also an apparent difference in denture function in relation to various food types, with Group 2 reporting higher function in relation to raw apples (8.2 difference). Group 2 reported a lower general satisfaction, with a difference of 11.4. However, there was a relatively large standard deviation (of 35.3) for the general satisfaction mean score for Group 2, indicating considerable variation. Not one of the apparent differences was statistically significant.

Data on the change in baseline mean satisfaction score following the first intervention with a lingualized

TABLE 3 Change in Baseline Mean Satisfaction Score after First Intervention (Lingualized Occlusion) (SD in Brackets)†

	Group 1 Mandibular implants only ($n = 4$)	Group 2 Maxillary and mandibular implants ($n = 4$)	Combined groups ($n = 8$)
Overall acceptance of dentures			
General satisfaction‡	−6.6 (34.7)	15.7 (41.7)	4.5 (37.5)
Ease of cleaning	23.8 (21.3)	13.2 (9.9)	18.5 (16.4)
Ability to speak	−15.5 (33.1)	1.5 (7.4)	−7.0 (24.0)
Comfort	−22.3 (34.1)	15.2 (37.7)	−3.5 (38.9)
Appearance	−2.0 (6.9)	22.5 (37.7)	10.2 (28.3)
Stability	−5.7 (51.7)	21.7 (40.8)	8.0 (45.6)
Oral condition, general	−18.0 (45.9)	−1.5 (11.5)	−9.7 (32.2)
Ability of dentures to chew various food types			
Ability to chew, general‡	−17.0 (49.7)	9.2 (13.7)	−3.8 (36.6)
Ability to chew, fresh white bread	9.5 (9.1)*2	4.3 (4.7)*1	6.4 (6.3)*3
Ability to chew, hard cheese	−10.0 (50.3)*1	−1.7 (12.6)	−5.2 (30.7)*1
Ability to chew, raw carrots	12.5 (0.7)*2	15.5 (21.0)	14.5 (16.3)*2
Ability to chew, sliced cold meat	−13.7 (35.0)	9.2 (22.7)	−2.2 (29.9)
Ability to chew, sliced steak	−18.5 (36.4)	17.0 (29.3)	−0.7 (36.0)
Ability to chew, raw apples	−5.0 (39.8)	−2.5 (10.4)	−3.7 (26.9)
Ability to chew, lettuce	−9.7 (36.5)	8.5 (8.8)	−0.6 (26.4)
Function of dentures in relation to various food types			
Function, general‡	1.5 (11.3)	8.2 (6.6)	4.8 (9.3)
Function, fresh white bread	4.5 (3.5)*2	11.6 (14.1)*1	8.8 (10.8)*3
Function, hard cheese	0.0 (26.2)*1	17.2 (23.4)	9.8 (24.3)*1
Function, raw carrots	−7.0 (25.4)*2	19.2 (25.9)	10.5 (26.7)*2
Function, sliced cold meat	−5.2 (6.3)	19.5 (27.8)	7.1 (22.9)
Function, sliced steak	−7.7 (9.7)	15.7 (22.2)	4.0 (20.2)
Function, raw apples	−1.0 (13.7)	8.2 (12.8)	3.6 (13.2)
Function, lettuce	−13.3 (17.3)*1	9.0 (13.5)	−0.5 (18.3)*1

*Indicates the number of nonresponses for question.
†The score is based on a satisfaction scale (visual analogue scale) from 0 to100, with a higher number indicating a higher satisfaction.
‡Key indicator questions.

occlusion are presented in Table 3. Group 1 reported a moderate decrease in satisfaction in most areas except for ease of cleaning, ability to chew fresh white bread, and function in general. While Group 2 reported a moderate increase in satisfaction in most areas; they did on average report a decrease in the ability to chew hard cheese or raw apples. The three largest differentials between the two groups were in respect to comfort, stability, and the ability to chew sliced steak.

Data on the change in baseline mean satisfaction score after the first intervention with a physiologic occlusion are presented in Table 4. There was a noticeable increase reported for both groups in all of the sections relating to function, although that for general function was mixed. However, Group 1 did report a minimal decrease in general satisfaction, ability to chew hard cheese and carrots. Group 2 reported a decrease in comfort and their ability to speak, and the sections relating to the ability to chew various foods were mixed with a slight decrease in the ability to chew in general. If these results are generalized, a moderate increase in satisfaction was observed in the combined groups mean results.

The changes in baseline mean satisfaction score after the second intervention (lingualized occlusion) are presented in Table 5. In general, a decrease in satisfaction had occurred, with Group 1 showing a moderate to large decrease in satisfaction in all key indicator questions. Group 2 also had a decrease in satisfaction in key

TABLE 4 Change in Baseline Mean Satisfaction Score after First Intervention (Physiologic Occlusion) (SD in Brackets)†

	Group 1 Mandibular implants only ($n = 5$)	Group 2 Maxillary and mandibular implants ($n = 5$)	Combined groups ($n = 10$)
Overall acceptance of dentures			
General satisfaction‡	−7.2 (25.9)	3.6 (33.0)	−1.8 (28.5)
Ease of cleaning	17.8 (21.7)	−3.6 (5.4)	7.1 (18.6)
Ability to speak	19.6 (28.8)	−12.8 (24.1)	3.4 (30.3)
Comfort	7.6 (14.9)	−10.6 (36.6)	−1.5 (28.0)
Appearance	18.0 (30.2)	−1.6 (13.6)	8.2 (24.4)
Stability	3.6 (7.3)	1.2 (32.0)	2.4 (21.9)
Oral condition, general	19.6 (22.1)	2.6 (5.8)	11.1 (17.7)
Ability of dentures to chew various food types			
Ability to chew, general‡	11.6 (18.3)	−2.7 (16.6)*1	5.2 (18.1)*1
Ability to chew, fresh white bread	13.7 (42.2)*1	1.7 (21.7)*1	7.7 (31.7)*2
Ability to chew, hard cheese	−1.0 (14.6)	4.6 (12.3)*2	1.1 (13.2)*2
Ability to chew, raw carrots	−2.8 (11.0)	−1.4 (11.8)	−2.1 (10.8)
Ability to chew, sliced cold meat	4.2 (8.4)	−1.0 (12.0)	1.6 (10.2)
Ability to chew, sliced steak	14.8 (23.9)	1.4 (21.9)	8.1 (22.8)
Ability to chew, raw apples	7.6 (24.2)	−1.2 (8.6)	3.2 (17.7)
Ability to chew, lettuce	0.5 (39.2)	−1.8 (18.4)	−0.6 (28.9)
Function of dentures in relation to various food types			
Function, general‡	5.6 (17.9)	1.8 (17.4)	3.7 (16.8)
Function, fresh white bread	11.7 (29.0)*1	15.6 (23.1)*2	13.4 (24.5)*3
Function, hard cheese	11.0 (17.2)	19.6 (12.5)*2	14.2 (15.3)*2
Function, raw carrots	3.4 (21.8)	8.0 (19.4)	5.7 (19.6)
Function, sliced cold meat	11.2 (18.9)	6.6 (18.6)	8.9 (17.9)
Function, sliced steak	11.4 (18.2)	8.8 (22.9)	10.1 (19.5)
Function, raw apples	15.0 (21.4)	5.2 (17.3)	10.1 (19.1)
Function, lettuce	7.2 (31.0)	8.6 (24.1)	7.9 (26.2)

*Indicates the number of nonresponses for question.
†The score is based on a satisfaction scale (visual analogue scale) from 0 to100, with a higher number indicating a higher satisfaction.
‡Key indicator questions.

indicator questions, but it was minimal, with some functional sections showing a minimal improvement.

Data on the change in baseline mean satisfaction score after the second intervention (physiologic occlusion) are presented in Table 6. For Group 1 there was a moderate decrease in satisfaction for all key indicator questions; however, there was an increase in satisfaction for ease of cleaning, stability, chewing, and function related to hard cheese. For Group 2, in general, there was an increase in satisfaction in most areas, except for a small decrease in the ability to chew fresh white bread and hard cheese. Their ability to chew raw apples and lettuce was decreased by a considerable amount.

Tables 7 and 8 present data on the change in the mean satisfaction score in relation to the two new occlusions with the order that the participants received the occlusions as the differential. Table 7 presents the data on the first intervention (physiologic occlusion) compared to the second intervention (lingualized occlusion). In general, a decrease in satisfaction with the lingualized occlusion was observed in both groups. Group 1 showed a moderate to significant decrease in satisfaction in all sections, while Group 2 had a minimal to moderate decrease in satisfaction.

Table 8 presents the data on the change in the mean satisfaction score for the groups that received the

TABLE 5 Change in Baseline Mean Satisfaction Score after Second Intervention (Lingualized Occlusion) (SD in Brackets)†

	Group 1 Mandibular implants only ($n = 5$)	Group 2 Maxillary and mandibular implants ($n = 5$)	Combined groups ($n = 10$)
Overall acceptance of dentures			
General satisfaction‡	−20.0 (40.6)	−1.8 (27.8)	−10.9 (34.1)
Ease of cleaning	3.0 (20.6)	7.8 (17.3)	5.4 (18.1)
Ability to speak	7.6 (33.9)	−24.8 (18.7)	−8.6 (30.9)
Comfort	−19.2 (42.1)	−11.0 (27.1)	−15.1 (33.7)
Appearance	−18.2 (39.1)	−11.4 (23.6)	−14.8 (30.7)
Stability	−4.0 (15.0)	−12.2 (19.8)	−8.1 (17.1)
Oral condition, general	1.2 (20.1)	4.0 (15.2)	2.6 (16.9)
Ability of dentures to chew various food types			
Ability to chew, general‡	−19.0 (18.1)	−2.7 (9.5)*1	−11.7 (16.5)*1
Ability to chew, fresh white bread	−7.7 (52.4)*1	−3.7 (7.7)*1	−5.7 (34.7)*2
Ability to chew, hard cheese	−11.8 (24.0)	−11.5 (14.5)*1	−11.6 (19.2)*1
Ability to chew, raw carrots	-9.0 (21.5)	−9.4 (16.5)	−9.2 (18.1)
Ability to chew, sliced cold meat	−7.2 (10.8)	−10.2 (9.6)	−8.7 (9.8)
Ability to chew, sliced steak	−1.0 (21.0)	−4.4 (15.5)	−2.7 (17.5)
Ability to chew, raw apples	−4.2 (27.3)	−7.2 (7.9)	−5.7 (19.0)
Ability to chew, lettuce	−25.7 (52.5)	−8.0 (4.8)	−16.8 (36.4)
Function of dentures in relation to various food types			
Function, general‡	−16.6 (27.0)	−3.0 (9.0)	−9.8 (20.3)
Function, fresh white bread	−15.2 (46.6)*1	5.7 (11.1)*1	−4.7 (33.3)*2
Function, hard cheese	−14.0 (27.0)	3.5 (9.2)*1	−6.2 (21.9)*1
Function, raw carrots	−11.4 (30.1)	−1.0 (9.6)	−6.2 (21.8)
Function, sliced cold meat	−10.0 (25.4)	−1.6 (9.5)	−5.8 (18.6)
Function, sliced steak	−9.4 (23.8)	3.2 (14.6)	−3.1 (19.8)
Function, raw apples	−4.0 (28.7)	−2.8 (10.0)	−3.4 (20.3)
Function, lettuce	−13.4 (47.7)	2.8 (11.3)	−5.3 (33.7)

*Indicates the number of nonresponses for question.
†The score is based on a satisfaction scale (visual analogue scale) from 0 to 100, with a higher number indicating a higher satisfaction.
‡Key indicator questions.

occlusions in the opposite order. Group 1 in general showed a decrease in the mean satisfaction score for the physiologic occlusion. Group 2 showed a minimal increase in overall acceptance of the denture, with a minimal to moderate decreased score in the sections related to chewing and function.

Table 9 shows the modeling of satisfaction scores for the three main key indicator questions and shows that there were no significant differences between the two groups with respect to general satisfaction, the general ability to chew, or general function. The period is indicated to determine whether the order in which participants received the occlusion was important. Although not statistically significant, there were hints of a period effect with general satisfaction, the general ability to chew, and general function. The results from the constant used in the general linear model shows that the variance of the data was constant ($p < 0.001$).

Participants' Comments about the Different Occlusions

Qualitative information on the participants' perceptions and preferences was also obtained. The main positives reported for lingualized occlusion were that it had better stability, with more freedom, and greater ease of adaptation. The defining differential statements for physiologic occlusion were based on participants' greater ability of the teeth to penetrate and chew food,

TABLE 6 Change in Baseline Mean Satisfaction Score after Second Intervention (Physiologic Occlusion) (SD in Brackets)†

	Group 1 Mandibular implants only (*n* = 3)	Group 2 Maxillary and mandibular implants (*n* = 4)	Combined groups (*n* = 7)
Overall acceptance of dentures			
General satisfaction‡	−11.3 (28.9)	16.0 (36.7)	4.2 (34.1)
Ease of cleaning	14.3 (19.6)	24.7 (17.3)	20.2 (17.6)
Ability to speak	−7.3 (13.6)	−0.7 (9.4)	−3.5 (10.9)
Comfort	−17.3 (26.9)	16.5 (36.5)	2.0 (35.1)
Appearance	−2.0 (6.0)	22.5 (38.1)	12.0 (30.1)
Stability	7.3 (61.6)	22.7 (39.7)	16.1 (46.0)
Oral condition, general	−3.3 (18.2)	8.7 (16.6)	3.5 (17.0)
Ability of dentures to chew various food types			
Ability to chew, general‡	−6.6 (39.7)	6.0 (20.8)	0.5 (28.0)
Ability to chew, fresh white bread	−6.3 (30.9)	−3.3 (17.0)*1	−4.8 (22.4)*1
Ability to chew, hard cheese	1.0 (32.5)*1	−1.7 (12.8)	−0.8 (17.6)*1
Ability to chew, raw carrots	−3.5 (28.9)*1	13.7 (34.0)	8.0 (30.7)*1
Ability to chew, sliced cold meat	−1.6 (19.1)	10.0 (32.0)	5.0 (25.9)
Ability to chew, sliced steak	−9.0 (33.4)	8.0 (34.6)	0.7 (32.4)
Ability to chew, raw apples	−2.0 (34.5)	−9.2 (11.6)	−6.1 (21.9)
Ability to chew, lettuce	−1.6 (36.0)	−29.2 (41.3)	−17.4 (38.8)
Function of dentures in relation to various food types			
Function, general‡	−10.3 (25.1)	−0.2 (23.0)	−4.5 (22.4)
Function, fresh white bread	−11.0 (22.6)	5.0 (24.6)*1	−3.0 (22.8)*1
Function, hard cheese	3.0 (27.7)	13.5 (35.2)	9.0 (30.1)
Function, raw carrots	−15.5 (30.4)*1	11.0 (38.7)	2.1 (35.6)*1
Function, sliced cold meat	−9.6 (25.8)	11.2 (40.3)	2.2 (34.1)
Function, sliced steak	−11.3 (26.6)	8.5 (37.0)	0.0 (32.1)
Function, raw apples	−4.6 (33.8)	3.7 (35.5)	0.1 (32.1)
Function, lettuce	−26.0 (36.7)*1	1.7 (35.1)	−7.5 (34.8)*1

*Indicates the number of nonresponses for question.
†The score is based on a satisfaction scale (visual analogue scale) from 0 to 100, with a higher number indicating a higher satisfaction.
‡Key indicator questions.

and the benefit of the larger size of the teeth. Considering that most participants had not had their own natural teeth for more than two decades, it was noteworthy that some participants commented that the physiologic posterior teeth appeared "more natural." The negative aspects reported for the physiologic occlusion were focused on problems associated with adapting to the denture occlusion. The steepness of the cusps and the more positive centric relation resulted in four participants commenting on a lack of freedom, and subsequent denture instability.

Seven participants found it easier to adapt to the lingualized occlusion, with another seven reporting no difference and a further two finding it easier to adapt to the physiologic occlusion. Of the other seven who found it easier to adapt to the lingualized occlusion, four selected it as their final occlusion, and the other three selected the physiologic occlusion as their preferred occlusion in spite of initial adaptation difficulties. The two participants who found lingualized occlusion more difficult to adapt to selected physiologic occlusion. Seven participants found no difference in the time it took them to adapt to the different occlusions. Six of them selected physiologic occlusion as their preferred occlusion.

Of the five participants who preferred lingualized occlusion, three had issues associated with the denture design. For the latter, the occlusion was most likely a

TABLE 7 Change in First Intervention (Physiologic Occlusion) Mean Satisfaction Score after Second Intervention (Lingualized Occlusion) (SD in Brackets)†

	Group 1 Mandibular implants only ($n = 5$)	Group 2 Maxillary and mandibular implants ($n = 5$)	Combined groups ($n = 10$)
Overall acceptance of dentures			
General satisfaction‡	−12.8 (38.3)	−5.4 (8.9)	−9.1 (26.5)
Ease of cleaning	−14.8 (41.2)	11.4 (20.9)	−1.7 (33.8)
Ability to speak	−12.0 (32.9)	−12.0 (17.2)	−12.0 (24.7)
Comfort	−26.8 (37.5)	−0.4 (19.0)	−13.6 (31.3)
Appearance	−36.2 (49.2)	−9.8 (15.1)	−23.0 (37.0)
Stability	−7.6 (14.8)	−13.4 (19.0)	−10.5 (16.4)
Oral condition, general	−18.4 (20.9)	1.4 (18.0)	−8.5 (21.1)
Ability of dentures to chew various food types			
Ability to chew, general‡	−30.8 (30.8)	0.0 (15.8)	−15.3 (28.1)
Ability to chew, fresh white bread	−21.5 (11.0)*1	−5.5 (16.7)*1	−13.5 (15.6)*2
Ability to chew, hard cheese	−10.8 (11.0)	−18.6 (10.2)*2	−13.7 (10.7)*2
Ability to chew, raw carrots	−6.2 (12.6)	−8.0 (15.2)	−7.1 (13.2)
Ability to chew, sliced cold meat	−11.4 (9.9)	−9.2 (14.5)	−10.3 (11.8)
Ability to chew, sliced steak	−15.8 (12.9)	−5.8 (12.3)	−10.8 (13.0)
Ability to chew, raw apples	−11.8 (7.6)	−6.0 (11.5)	−8.9 (9.7)
Ability to chew, lettuce	−26.2 (19.6)	−6.2 (15.4)	−16.2 (19.7)
Function of dentures in relation to various food types			
Function, general‡	−22.2 (24.2)	−4.8 (11.8)	−13.5 (20.2)
Function, fresh white bread	−27.0 (27.5)*1	−10.3 (11.2)*2	−19.8 (22.3)*3
Function, hard cheese	−25.0 (28.4)	−11.6 (10.5)*2	−20.0 (23.2)*2
Function, raw carrots	−14.8 (19.2)	−9.0 (13.6)	−11.9 (16.0)
Function, sliced cold meat	−21.2 (23.0)	−8.2 (14.2)	−14.7 (19.3)
Function, sliced steak	−20.8 (23.0)	−5.6 (12.4)	−13.2 (19.2)
Function, raw apples	−19.0 (26.1)	−8.0 (12.9)	−13.5 (20.3)
Function, lettuce	−20.6 (25.2)	−5.8 (16.2)	−13.2 (21.4)

*Indicates the number of nonresponses for question.
†The score is based on a satisfaction scale (visual analogue scale) from 0 to 100, with a higher number indicating a higher satisfaction.
‡Key indicator questions.

factor, but it was not clear whether it was the overriding factor. In contrast, only one of the 10 participants who preferred physiologic occlusion had these issues.

For those who selected the physiologic occlusion, the overriding factors were improved chewing ability and the greater size of the posterior denture teeth. One qualitative statement made by a participant was "*lingualized teeth were an improvement over any previous dentures that I have had, but the physiologic teeth were even better. I was content with my old implant dentures because I did not know how good implant dentures could be*." As implied by this statement, participants felt that the physiologic teeth were generally better than anything they had experienced previously. Other statements about the occlusion were "*physiologic looked better – felt better – looked like natural teeth – sharper – quicker chewing of food*."

In general, when participants were commenting about lingualized occlusion, they mentioned how easy the dentures were to adapt to and that they did not notice much difference compared to other dentures they had experienced. An example of a typical statement about the lingualized occlusion was "*I got used to lingualized teeth quicker and the physiological teeth took longer to get used to* (on average 2 weeks), *lingualized teeth took no adjustment*." The key issue that emerged from the interviews and the qualitative data was that, if the participant was adaptive[24] and did not have underlying denture

TABLE 8 Change in First Intervention (Lingualized Occlusion) Mean Satisfaction Score after Second Intervention (Physiologic Occlusion) (SD in Brackets)†

	Group 1 Mandibular implants only ($n = 3$)	Group 2 Maxillary and mandibular implants ($n = 4$)	Combined groups ($n = 7$)
Overall acceptance of dentures			
General satisfaction‡	−21.5 (18.7)	0.2 (5.6)	−9.0 (16.3)
Ease of cleaning	−0.8 (6.2)	11.5 (20.3)	6.2 (16.2)
Ability to speak	−8.3 (11.9)	−2.2 (3.5)	−4.8 (8.0)
Comfort	−11.8 (28.6)	1.2 (12.3)	−4.3 (19.9)
Appearance	−3.0 (1.7)	0.0 (6.6)	−1.2 (5.0)
Stability	−4.6 (16.5)	1.0 (3.1)	−1.4 (10.2)
Oral condition, general	−8.0 (12.1)	10.2 (26.5)	2.4 (22.2)
Ability of dentures to chew various food types			
Ability to chew, general‡	−14.3 (34.7)	−3.2 (11.9)	−8.0 (22.5)
Ability to chew, fresh white bread	−19.0 (33.9)*1	−7.6 (17.0)*1	−12.2 (21.7)*2
Ability to chew, hard cheese	−18.0 (28.2)*1	0.0 (20.4)	−6.0 (22.2)*1
Ability to chew, raw carrots	−16.0 (29.6)*1	−1.7 (21.8)	−6.5 (22.7)*1
Ability to chew, sliced cold meat	−5.3 (15.6)	0.7 (23.4)	−1.8 (19.1)
Ability to chew, sliced steak	−8.3 (24.5)	−9.0 (18.3)	−8.7 (19.2)
Ability to chew, raw apples	−16.3 (36.3)	−6.7 (18.2)	−10.8 (25.1)
Ability to chew, lettuce	−10.0 (38.9)	−37.7 (39.5)	−25.8 (38.8)
Function of dentures in relation to various food types			
Function, general‡	−17.0 (28.5)	−8.5 (17.7)	−12.1 (21.2)
Function, fresh white bread	−21.0 (25.4)*1	−6.6 (13.4)*1	−12.4 (17.7)*2
Function, hard cheese	−19.0 (29.6)*1	−3.7 (17.0)	−8.8 (20.3)*1
Function, raw carrots	−8.5 (55.8)*1	−8.2 (21.2)	−8.3 (29.9)*1
Function, sliced cold meat	−4.6 (31.2)	−8.2 (20.5)	−6.7 (23.2)
Function, sliced steak	−3.6 (32.6)	−7.2 (22.0)	−5.7 (24.5)
Function, raw apples	−10.3 (33.7)	−4.5 (27.5)	−7.0 (27.6)
Function, lettuce	2.6 (49.0)	−7.2 (27.8)	−3.0 (34.9)

*Indicates the number of nonresponses for question.
†The score is based on a satisfaction scale (visual analogue scale) from 0 to 100, with a higher number indicating a higher satisfaction.
‡Key indicator questions.

problems, the physiologic occlusion was deemed to have superior function. However, if there were either adaptation or underlying denture problems, there was a higher acceptance of the lingualized occlusion.

The main reasons given for preferring the physiologic occlusion were chewing ability/food penetration ($n = 7$), stability/better retention ($n = 3$), and esthetics ($n = 1$).

The main reasons given for not preferring the physiologic occlusion were reduced chewing ability compared to lingualized occlusion ($n = 2$), poor retention ($n = 2$), and lack of freedom ($n = 1$).

The main reasons given for preferring the lingualized occlusion were chewing ability ($n = 2$), stability/better retention ($n = 2$), and freedom ($n = 1$).

The main reasons given for not preferring the lingualized occlusion were reduced chewing ability compared to physiologic occlusion ($n = 7$) and poor retention ($n = 1$).

DISCUSSION

The objective of this research was to compare a physiologic occlusal scheme with a lingualized occlusal scheme with respect to patient's satisfaction levels with

TABLE 9 Outcomes of General Linear Models for Patient Satisfaction Scores

Model	Coefficient	SE	*Z* statistic	*p* value
General satisfaction				
Occlusion	0.0905	0.1263	0.72	0.47
Group	−0.1401	0.3624	−0.39	0.69
Period	−0.2161	0.1263	−1.71	0.08
Constant	4.8059	0.6425	7.48	<0.001
Ability to chew, general				
Occlusion	0.0997	0.1608	0.62	0.53
Group	−0.0903	0.4615	−0.20	0.84
Period	−0.2464	0.1608	−1.53	0.12
Constant	4.7564	0.8182	5.81	<0.001
Function, general				
Occlusion	0.0661	0.1445	0.46	0.64
Group	−0.3400	0.4147	−0.82	0.41
Period*	−0.2686	0.1445	−1.86	0.06
Constant**	5.2077	0.7352	7.08	<0.001

*The period is indicated to determine whether the order in which participants received the occlusion was important.
**The results from the constant used in the general linear model show that the variance of the data was constant ($p < 0.001$).

implant overdentures. The participants selected their preferred occlusion at the end of the study, based on their own subjective evaluations. The hypothesis that there would be no difference detected by the participants between the two occlusal schemes was not proved correct.

As there is limited research in the area of occlusal schemes and implant overdentures, a direct comparison of our findings with those of other studies is challenging. The difficulty in comparing our study with others is that they differ with regard to study design, outcome measures, clinical procedures, technical procedures, implant number, and the type of overdenture attachment systems used. Patients who receive implant overdentures, regardless of the extent of residual ridge resorption, have been reported to have added stability, increased biting force, and predictable masticatory function.[4,5,8,11,12,14,31–36] It has been suggested by some authors that lingualized occlusion be the standard occlusion for implant overdentures.[1,2,8,11] However, it is also relevant that recommended textbooks still allude to there being no clinical studies that demonstrate that lingualized occlusion has an advantage over any other for conventional complete dentures.[16]

We acknowledge the study's limitations with the most significant being the limited statistical power, with only 18 participants. The number of participants was limited by budgetary constraints, due to the high cost involved in this type of clinical study and the difficulty in securing suitable participants who were willing to assess the different occlusal schemes. There was also a substantial commitment of clinical and laboratory time associated with the clinical research. All the results were statistically nonsignificant ($p > 0.05$). However, to determine the effect of this statistical underpowering of the study, we repeated some of the cross tabulations using double the numbers. The statistical power of the cross tabulation, with a doubled *n* value, has a *p* value = 0.003; this indicates that the results of the cross tabulation if doubled would produce statistically significant results. Thus, it is apparent that resource and practical constraints led to the study being underpowered, rather than a poor study design. However, to control for a possible period effect, the order in which participants experienced the different occlusions was alternated. The concern was that the participants could have been influenced by the order in which they received the different occlusions. A potential source of bias was that the participants might be inclined to indicate a greater degree of satisfaction with their treatment if the clinician administered the questionnaires. To minimize this potential bias, a dental assistant was employed for this role. A

potential confounding factor for this research was the exchanging of patients' dentures (directly applicable to Group 1). It was important that only the posterior occlusion was noticeably altered, otherwise the participants would be influenced by factors such as the aesthetics and fit of the different dentures. This research controlled potential confounding factors by either the use of duplicate casts, or retaining the original denture fitting surfaces and retaining anterior teeth or duplicating their placement by means of the silicone matrices. By adopting these techniques, the participants should have based their satisfaction on the change of occlusion, rather than on an aesthetic change in the dentures.

The baseline satisfaction scores for participants prior to treatment were generally high, ranging from 67 to 100%. This was expected and is consistent with the high satisfaction levels observed in other randomized controlled clinical trials on implant overdenture patients.[4,11,35] This is an important factor to consider in our research when looking at the change in satisfaction levels after each intervention. For example, if a participant had a baseline satisfaction of 80 out of 100 and then they reported a decrease of 3 after an intervention, their satisfaction level is still relatively high. Moreover, a ceiling effect is present in some instances due to participants having a baseline score of 100 of the commencement of the research, meaning that any significant increase in the satisfaction level was not possible.

Groups 1 and 2 were distinguished by the fact that Group 2 had three implants in the edentulous maxilla also supporting an overdenture. However, when the two groups' satisfaction scores were modeled using the three main key indicator questions (general satisfaction, general ability to chew, or general function), there were no significant differences between them. Within the limitations of this study, this implies that participants with maxillary 3-implant overdentures and mandibular implant overdentures achieve the same satisfaction levels as those with mandibular 2-implant overdentures only. It is apparent that participants who did not have maxillary 3-implant overdentures had conventional maxillary dentures that were deemed as satisfactory.

By looking at the combined data for the participants who received lingualized occlusion as the first intervention, the overall pattern suggested that the lingualized occlusion was comparable to the pre-existing occlusion. With respect to general function, both groups reported an increase in satisfaction levels. The mean satisfaction scores for the second intervention (physiologic occlusion) reflected a slight increase in most areas except for that of general function.

The participants who received physiologic occlusion in the first intervention showed that (overall) they had a moderate increase in most areas (except for general satisfaction, which had a slight decrease). The most significant increases in satisfaction were related to the functional areas. When the change in satisfaction is added to the baseline, participants' satisfaction levels were at 80–90% for the physiologic occlusion. This reinforces the higher preference that participants had for the physiologic occlusion. However, the high satisfaction levels recorded relating to function are not reflected in the satisfaction levels relating to the ability of the denture to chew food. This could be linked to adaptation problems, or other denture-related issues, but the reason for this difference is unclear. These participants then received lingualized occlusion, which resulted in a general decrease of satisfaction, with Group 1 showing a moderate-to-large decrease in satisfaction in all key indicator questions. Group 2 also had a decrease in satisfaction according to key indicator questions; however, it was less significant, with some functional sections showing a minimal improvement. At this stage, participants would have been influenced by their previous experience, and some degree of comparison to the prior occlusion would have occurred.

On direct comparison of the two occlusions, the group that received physiologic occlusion first gave it a greater satisfaction rating. This, however, is the direct opposite of the outcome for the group that received the lingualized occlusion first. It is worthwhile to point out that this would account for the "hint" of a period effect that was evident in the multivariable model (although it was not statistically significant).

The final results indicate that more participants preferred a physiologic occlusion than a lingualized occlusion. Three out of five participants preferred a physiologic occlusion. Only the single crossover trial by Clough and colleagues[36] cited by the Cochrane Collaboration review,[6] on denture chewing surface designs in edentulous people with conventional dentures is directly comparable to our findings with implant overdentures. That study had similar participant numbers and asked participants to indicate their preference; its findings also suggested that patients prefer denture teeth with cusps because of their better chewing performance. While

limited evidence is available, it appears that an improvement in function is one key determinant of patient's satisfaction.

The ultimate and overriding objective of any prosthesis is to restore function and enhance patient psychosocial well-being,[24] and with this in mind, patient's perception of implant overdenture treatment has to be considered. This makes it just as important to understand the reasons for the participants' preferences, as it is to know the outcomes of those preferences. Thus, participants were asked to provide (both positive and negative) reasons for their selection of occlusion. These were useful in determining the rationale for the participant's choice of occlusion and in providing additional information to validate the findings. Participants who appeared adaptive[24] (and did not have underlying problems with their overdentures) during the qualitative assessment seemed to find the physiologic occlusion to be superior, while those who appeared to have problems with adaptation (or associated issues) preferred lingualized occlusion. The associated issues that influenced participants' choice were sore spots, food accumulation under dentures, and general dissatisfaction with their dentures. Of the five participants who preferred lingualized occlusion, three identified associated issues, while only one of the 10 participants who preferred physiologic occlusion had such issues. If a participant found the physiologic occlusion easier to adapt to, they invariably preferred it. This suggests that a maladaptive patient may have higher acceptance of a lingualized occlusion. This assertion is supported by the findings of Lang and Razzoog[1] and Parr and Ivanhoe,[37] who promoted lingualized occlusion as an approach that satisfies the needs of the majority of edentulous patients, with one of its main advantages being the ease with which patients can adapt to it.

For those who selected the physiologic occlusion, the overriding issues were improved chewing ability and the greater size of the occlusal table. This suggests that it is possible to increase patient's satisfaction even further by providing an occlusion that takes advantage of the stability that implants provide for dentures. The participants' reasons for selecting a physiologic occlusion are supported by Mehringer's[38] comments that the combination of stability and a higher cusp angle results in less chewing force necessary to penetrate food. The logical conclusion, that steeper cusps are more efficient at penetrating the bolus (resulting in less vertical force being required), is a point that should not be overlooked. The concern that the greater occlusal table will increase loading on the underlying structures was discounted by Swoope[39] and Kydd,[40] who showed that the size of the occlusal table did not have any significant effect on the deformation of the denture base.

The findings of our research still appear to support the assertions of Lang and Razzoog[1], Geertman and colleagues,[10,11] Kapur and colleagues,[41] Boerrigter and colleagues,[42] and Wismeijer and colleagues[43] that lingualized occlusion may satisfy the needs of the edentulous patient who has a conventional maxillary denture opposing mandibular 2-implant overdenture. Our findings should also be contrasted to those of very recent recommendations of Sutton and McCord.[44] Participants of a randomized clinical trial with conventional complete dentures found that those with lingualized or anatomic posterior occlusal forms exhibited higher levels of self-perceived patient satisfaction compared to those with zero-degree posterior occlusal forms.

It should be again emphasized that our findings do not reveal any difference in the occlusal scheme findings when the opposing arch has either a conventional maxillary denture or a maxillary 3-implant overdenture. All our participants had high baseline satisfaction levels (with their original prostheses) at the start of the research. During our research they also expressed high levels of satisfaction with both lingualized and physiological occlusions. However, in investigating this further (as this research has done), it is important to realize that, given the choice, participants in fact actually tended to prefer a physiologic occlusion. It was shown in this study that participants based their preference for physiological occlusion on their increased ability to masticate. It is important to remember that the participants had to adapt to a denture occlusion that was distinctly different from any that they had experienced in their denture-wearing lives. Despite adaptation problems, the majority of participants selected physiologic occlusion because of its better function. It is apparent that if aesthetics and comfort are satisfactory, denture function is of a high priority to patients. By selecting an occlusion for participants that improved their functional ability, it was possible to increase satisfaction levels over those recorded previously with their old dentures. Thus, it is possible to state that, if adequate patient selection were carried out, physiologic occlusion would result in better

patient satisfaction levels where implant overdentures are concerned.

CONCLUSIONS

The hypothesis that there would be no difference in the levels of patient satisfaction with a physiologic occlusal arrangement and a lingualized occlusal arrangement of the denture teeth for patients wearing implant overdentures was proved incorrect.

The majority of participants' experiences in wearing implant overdentures for more than 3 years indicated an overall preference for the physiologic occlusion arrangement of posterior teeth over a lingualized one. Improved function was the main reason given for that preference. This suggests that it is possible to improve patient's treatment outcomes for implant overdenture patients by selecting an occlusion that optimizes their function.

It is possible that when considering occlusal schemes for implant overdenture patients, traditional complete denture occlusal schemes (bilateral balance and lingualized) may not be the only definitive treatment option. It is accepted that this study is underpowered due to the limitations of the size of the study. However, this research suggests that a physiologic occlusion is more appropriate in certain implant overdenture patients and that it is possible to increase satisfaction levels by altering the occlusion even when participants are content with existing denture occlusion.

ACKNOWLEDGMENTS

We thank the participants in the Clinical Overdenture Research Project (CORP), Oral Implantology Research Group, Sir John Walsh Research Institute, School of Dentistry University of Otago. To Professors James Lund and Jocelyne Feine of McGill University, Montreal, Canada, for granting permission for the use of visual analogue questionnaires as part of a collaborative agreement. We also acknowledge the generosity of the following who supported the research: Ivoclar Vivadent Ltd New Zealand; Shalfoon Dental New Zealand for supplying the denture teeth, and Instuit Straumann, Switzerland; the ITI Research Foundation, Southern Implants Ltd South Africa and NobelBiocare (Australia) Pty Ltd for their previous support in terms of implant components.

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