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Management of Patients' Oral Rehabilitative Needs Across the Age Spectrum

**George A. Zarb**

*Editor-in-Chief*

**Official Journal of**

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George A. Zarb  
 Toronto, Ontario, Canada

**Assistant to the Editor**

Janet deWinter  
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## The Case for Unlearning

Steven J. Sadowsky, DDS

*One cannot step twice into the same river.*

—Heraclitus of Ephesus, 6th century BCE

When George Zarb, this Journal's Editor-in-Chief, facilitated the introduction of osseointegration in North America, a seismic disruption in our traditional approach to managing partial and complete edentulism ensued. It provoked two inconvenient concerns: (1) Has our embrace of established ways of thinking slowed the diffusion of new applications for implant restorations? (2) Have we rejected Joseph Schumpeter's concept of creative destruction, whereby a full adoption of an innovation must be followed by destroying old concepts and replacing them with new ones?<sup>1</sup> I believe both questions can be answered affirmatively.

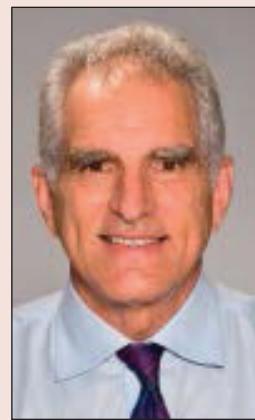
Robert Zajonc, a social psychologist, first described a phenomenon called cognitive fluency, which is an instinctive preference for the familiar. This concept explains why we process new information as though we have already seen it before. It is an adaptive shortcut that helps us allocate limited mental resources in a world of sensory overload. Information retrieved from memory has been found to be more fluent or familiar than when it was first learned and has been shown to lead to an increase in perceived validity.<sup>2</sup> For example, subjects judged food additives with labels that were difficult to pronounce as being more toxic than those that were easier to pronounce. When the pronunciation seemed facile, the subjects assumed it was safe because they had previously encountered the additive and had already done the mental work of establishing its safety.<sup>3</sup> Familiar was equated with safe.

While working on my new text, *Evidence-Based Implant Treatment Planning and Clinical Protocols*, it was apparent that familiar conventional dental principles dominated the delayed dissemination of implant-specific tenets. A number of examples illustrate this point, such as our imperfect understanding of peri-implant bone loss short-circuited by a blind acceptance of the periodontal model, despite differences in genesis and biology.<sup>4</sup> A critical analysis of the triad of the host, operator, and implant factors has revealed unique precursors and pathways of disease, with an untoward interfacial healing response linked to such variables as genetic or immune host disorders, bone volume deficiencies, inadequate alveolar/basal bone ratios, poor surgical technique/site selection, and imaging error.

Given that dental implants are not inert biomaterials, histologic evidence has demonstrated a series of specific cell lines that are consistent with a foreign body reaction in contradistinction to the presumed cellular cascade in so-called peri-implantitis.<sup>5</sup> A similar intransigent mindset underscores the sad fact that it took 17 years for tilted implants to be embraced as a viable alternative to augmentation.<sup>6</sup> The dentally driven notion that nonaxial forces could lead to marginal bone loss of implants also delayed a better understanding of an induced ankylosis-like interface. A similar mindset protracted the acceptance of short implants after the introduction of implant surface modifications.<sup>7</sup> Moreover, crown-to-root ratio dogmas were transferred to crown-to-implant ratios. It is only recently that researchers have demonstrated that crown-to-implant ratios up to 2.5 do not generate marginal bone loss,<sup>8</sup> while anachronistic maxims continued to be supported by in vitro studies. For more than two decades, splinting of posterior implants in partially edentulous patients was considered preferential to solitary units because it was "safer," as a 2008 finite element analysis demonstrated that splinting reduces the damage evolution in bone tissue.<sup>9</sup> Despite the low level of evidence, this bench study gained traction because it seemed intuitive. It was not until Paolo Vigolo<sup>10,11</sup> conducted 5- and 10-year split-mouth clinical studies revealing virtually no difference in marginal bone loss in the posterior maxilla with splinted and nonsplinted implant restorations that the practice of default splinting was questioned. Likewise, a 2016 finite element analysis assessing three-unit cantilever fixed implant prostheses documented that the cantilever extension can transfer excessive load to the bone around implants, leading to bone resorption.<sup>12</sup> However, this flies in the face of 5-year clinical data establishing the success of posterior implant cantilever prostheses.<sup>13</sup> Once again, the halo effect from the tooth-borne restorative playbook altered the perception of data. It is of note that acceptance of outcome-based implant restorative canons may reduce treatment cost, time, morbidity, and/or risk. The patient becomes the beneficiary as we discard familiar but irrelevant notions. With that hanging in the balance, what would foster a nimble thought process in response to innovation?

Karen Becker's studies bridged the gap between research and practice. She posited that sustaining change from innovation requires unlearning, a "process by which individuals and organizations acknowledge and release prior knowledge (assumptions and mental frameworks) in order to accommodate new information." Factors that can influence a faculty's unlearning in an academic environment have already been compellingly identified.<sup>14</sup> They involve making a strong case for why a new system is proposed. Individual faculties can lead the way here, and my own dental school has already embarked on an intensive faculty training program in evidence-based implant treatment planning rationales. Learning aids supplement our course and enhance the application of new information while addressing individual staff feelings and expectations during change implementation. It is a given that the emotional component of accepting new systems that inevitably affect established routines must not be overlooked. Finally, participating faculty's responses need to be recruited in the evaluation of the new system after its adoption. Constructive feedback encourages personal investment with suggestions for improvement and future research.

As we enter the Innovation Age, our profession—especially the Prosthodontic discipline—contends with the physics of the new movement by addressing inertia and momentum. When the concept of endosseous implants was embraced, we would only later understand the process of integration.



Dr Steven Sadowsky is professor and director of implant education at the University of the Pacific Arthur A. Dugoni School of Dentistry. He has practiced Prosthodontics full-time for 35 years and is past president of the American Prosthodontic Society and president-elect of the Pacific Coast Society for Prosthodontics. He is a diplomate of the American Board of Prosthodontists, directed the American College of Prosthodontists Annual Review Course for the last 5 years, and is the recipient of the 2016 American College of Prosthodontists Presidential Citation. Dr Sadowsky's *Evidence-Based Implant Treatment Planning and Clinical Protocols* will be published in late 2016.

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## 2016 Frechette Awards

The winners of the 2016 Frechette Awards were recently presented at the International Association for Dental Research (IADR) annual meeting in Seoul, Republic of Korea. The Frechette is an annual research competition for new investigators sponsored by the Prosthodontics Group of the International Association for Dental Research and honoring the memory of Arthur R. Frechette, who served as Secretary-Treasurer of the IADR from 1968 to 1977. The winners were Dr Emilio Hara, Okayama University, Okayama-shi, Japan, for "Chondrocyte Burst Promotes Space for Mineral Expansion During Initial Mineralization," and Dr Candida Parisi, University of Bologna, Bologna, Italy, for "Translucency of Monolithic Hybrid Cubic/Tetragonal Zirconia Crowns: A Comparative Study." In addition to the plaques they received, Drs Hara and Parisi were each awarded \$1,000 thanks to the generous support of the Whip Mix Corporation.

New investigators in prosthodontics are encouraged to apply for one of two 2017 Arthur R. Frechette Research Awards in Prosthodontics. Each award recognizes original research by new investigators and is again sponsored by the Prosthodontics Group of the IADR and supported by the Whip Mix Corporation. One award is for prosthodontic research undertaken from a materials science or bioengineering orientation,

and the other is for prosthodontic research undertaken with a biological sciences and tissue engineering-oriented protocol. Researchers carrying out original research are eligible for the Frechette Award if they have been the primary author of no more than three articles published in peer-reviewed dental journals. Each award carries a cash prize of \$1,000.

Research submitted for the IADR meeting in San Francisco, California is eligible for consideration for the Frechette Award, provided it has not been published elsewhere or will not be under consideration for another award. Abstracts must be submitted to the Prosthodontics Group of the IADR by the IADR deadline, with the appropriate boxes checked on the online submission form.

The abstracts will be judged based on (1) originality and scientific design of the investigation, (2) suitability of the methods of analysis, and (3) scientific value of the work. Selected finalists will be judged at the 2017 IADR meeting in San Francisco, California (March 22–25, 2017), and the winner will be announced at the Prosthodontics Group Business Meeting.

Stephen F. Rosenstiel, BDS, MSD  
rosenstiel.1@osu.edu



(left to right) Dr David Bartlett, President, IADR Prosthodontics Group; Dr Jamila Almuhamadi, Barts and the London School of Dentistry, London, UK, Frechette Award Finalist; Dr Hara, Frechette Award Winner; Dr Parisi, Frechette Award Winner; Dr Lianyi Xu, Ninth People's Hospital, Shanghai Jiao Tong University, School of Medicine, Shanghai, China, Frechette Award Finalist; and Dr Stephen F. Rosenstiel, Frechette Coordinator, IADR Prosthodontics Group.

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Page no. 550 which include international advertisements of no relevance have been omitted,  
to keep the contents limited to academics only.

# Single-Implant Survival: More Than 30 Years of Clinical Experience

Torsten Jemt, DDS, Odont Dr, PhD<sup>1</sup>

**Purpose:** The aim of this study was to report long-term clinical survival of single implants provided with turned and moderately rough surfaces in routine practice. **Materials and**

**Methods:** All patients consecutively treated at a specialist center with single-crown implants from 1982 to 2013 were included. For all these patients, data on implant failure and last examination at the clinic were collected, and thereafter cumulative survival rates (CSR) were calculated for patients treated in the maxilla or mandible with turned or moderately rough surfaces, respectively. **Results:** In total, 2,417 patients (2,665 operations) were treated with 3,211 single implants during the inclusion period (31 years). Of these, 573 (615 operations, 754 implants) were followed up for at least 10 years. Overall proportions of patients followed up for 5 years up to 25 years decreased from 68.2% to 37.0% of treated patients. A higher follow-up compliance was observed for patients treated during the earlier period of inclusion. Patient CSR for 15 and 10 years for maxillary implant placement was 95.8% for turned surfaces and 98.5% for moderately rough surfaces, respectively. Corresponding patient CSR for 10 and 25 years for mandibles was 95.1% and 97.2%, respectively. No implant was reported as a failure after 10 years of follow-up. **Conclusion:** A significant number of patients can be expected to be lost to follow-up during long-term periods in routine practice. Single-implant treatment is an overall predictable treatment procedure over the long term, with a lower failure rate for implants with a moderately rough surface placed in the maxilla. This difference seems to be established already during the early phase of osseointegration. *Int J Prosthodont* 2016;29:551–558. doi: 10.11607/ijp.4892

The original Bränemark concept to restore patients with osseointegrated dental implants was first designed for the edentulous patient in the mid 1960s.<sup>1,2</sup> After almost 18 years of development and clinical documentation of this treatment, the very first patient received an osseointegrated implant to restore a single missing tooth.<sup>3,4</sup> Few single implants were placed during the early years that followed, but use of the single-implant technique increased after further modifications and development.<sup>3–9</sup> Currently, it is probably the most common implant treatment protocol worldwide. Accordingly, it must be assumed that millions of patients have received one or several single-implant restorations worldwide, predominantly in a population that is younger than the original edentulous implant population. With such a large number

of patients with a long expected remaining lifetime, it is important to have long-term clinical evidence for the treatment protocol. Dental implants were controversial in the early days of osseointegration, and the Bränemark team had to collect 10 to 15 years' follow-up data on the initial treatment protocol for edentulous patients before osseointegration was accepted in the dental community.<sup>1,2</sup> With regard to numbers and age of patients treated with single implants today, it should be expected that the treatment is based on solid long-term clinical evidence. However, recent reviews on single-implant protocols have shown that only about 400 patients worldwide are documented up to 10 years, and even fewer with implants with a modern medium rough surface.<sup>10,11</sup>

Accordingly, single-implant treatment has been documented as a successful procedure<sup>4,5,7,9,12,13</sup> with predictable results for 5 years and, to a limited extent, up to 10 years of follow-up.<sup>10,11</sup> However, survival data on even longer periods are very limited on single implants provided with a moderately rough surface, and it is unclear if available favorable results can be maintained for longer periods without unexpected increase of implant failures over time. To reflect the large population of single-implant patients currently treated worldwide, it would be favorable to collect implant survival data from a larger population of implant

<sup>1</sup>Prosthodontist, Bränemark Clinic, Public Dental Health Service, Region of Västra Götaland, Sweden; Professor, Department of Prosthetic Dentistry/Dental Material Science, Institute of Odontology, Sahlgrenska Academy at Göteborg University, Göteborg, Sweden.

**Correspondence to:** Dr Torsten Jemt,  
Bränemarkkliniken Medicinaregatan, 12C SE 413 90 Göteborg, Sweden.  
Email: torsten.jemt@vgregion.se

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patients treated and followed up under more routine clinical circumstances (effectiveness) as compared with survival rates from a smaller, well-controlled population, treated and followed up under optimal conditions (efficacy).

The aim of the present study was to report long-term clinical survival of single implants consecutively placed on a routine basis at one clinic from 1982 to 2013. The focus of the present study is survival of implants still in function in routine practice.

## Materials and Methods

The present study is a retrospective register/observation study<sup>14,15</sup> based on all single-implant operations consecutively performed from 1982 to 2013 (31 years) using osseointegrated dental implants at the University of Gothenburg from 1982 to December 1985 and thereafter at the Bränemark Clinic (Public Dental Health Service in Region of Västra Götaland, Sweden). The study has been approved by the local ethical committee in Göteborg (no. 197-12).

In total, 9,124 patients were provided with 41,897 implants at 11,450 operations during the inclusion period. Altogether, 29,891 Bränemark System implants (Nobel Biocare) with a turned surface were consecutively placed from 1982 to 2004, and 12,006 implants provided with a moderately rough surface were consecutively placed between 2001 and 2013. Most of the implants with a moderately rough surface were Bränemark System implants with a gradient TiUnite surface (95.7%).

In the early period of inclusion, implant surgery was performed after a healing period of at least 1 to 3 months after tooth extraction. Bränemark System implants with a turned surface were placed according to a standard two-stage surgical protocol.<sup>16</sup> The two-stage protocol was maintained for most operations in the maxilla after introduction of implants with a moderately rough surface.<sup>17-19</sup> For the mandible, however, a one-stage surgical protocol was introduced on a routine basis at the clinic in connection with the use of implants with a moderately rough surface.<sup>17-19</sup>

The first patient treated with osseointegrated implants was restored in the edentulous mandible in 1965 by the Bränemark team,<sup>1,2</sup> followed by the first patient restored in the partially edentulous mandible in 1968. However, the first patient provided with one osseointegrated implant to restore a missing single tooth was treated 14 years later, in 1982.<sup>4</sup>

All-single implant patients consecutively treated by the original Bränemark team and later at the Bränemark clinic up to 2013 have been included in the present study. Patients included in

the study were all those that have been provided with single implants in the maxilla and/or mandible and thereafter restored with crowns based on different single-abutment techniques.<sup>3-9</sup> The protocol and components for treatment of patients with single-implant crown restorations was developed by the original Bränemark team at the University of Gothenburg.<sup>3,4</sup> Various techniques and components have been used for the single-crown restorations during the years, initially designed as premachined components and later as custom abutments, fabricated in both titanium and ceramics.<sup>3-9</sup> A special healing abutment was introduced as well due to the logistic protocol for single-implant treatment. All single crowns were cemented to the premachined abutments, most often outside the mouth, and then secured through an access hole. For the majority of the custom abutments, crowns were baked directly to the abutment and secured by means of an access hole through the crown-abutment restoration. All patients treated at the clinic were referral patients who were followed up by the referring dentists after prosthetic treatment. More recently, patients have also been referred to the clinic for implant surgery only and subsequent restorative treatment has been performed by the referring dentists. As a routine protocol, all patients have been invited to participate in a follow-up program at the clinic and examined after 1 year and then every 5 years.<sup>15</sup> Year of implant surgery and year of last visit to the clinic has been recorded to report time of patient follow-up and when patients were lost to follow-up.

Basic data was collected regarding age and sex of patients at implant operation, time and jaw at surgery, number and type of installed implants, and lost implants and time of last visit at the clinic. The primary endpoints in this study were implant failure and time of follow-up. Patients have been followed up from the first implant operation in 1982 to December 2014, covering at least 1 year of follow-up for those patients treated in 2013.

## Statistical Analyses

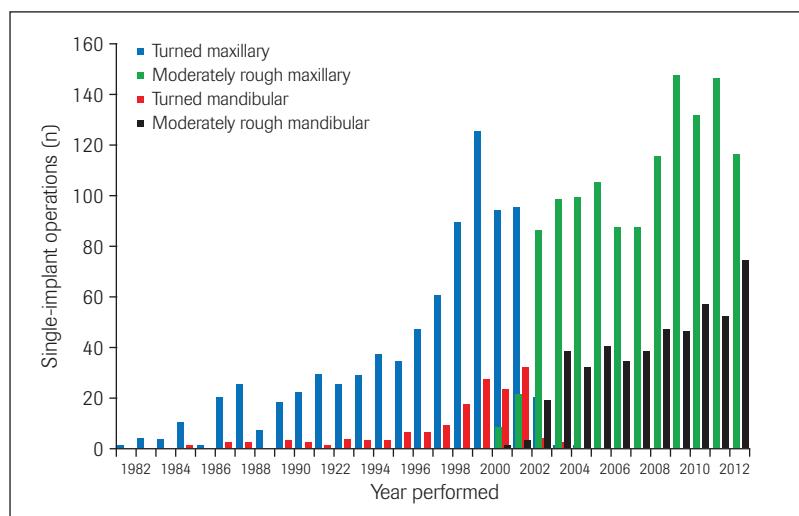
In the present study, data are presented as numbers, frequencies, means, and standard deviations. Life tables have been calculated according to methods described by Kaplan and Meier.<sup>20</sup> Calculations of cumulative survival rate (CSR) were performed up to the year when at least 25 patients were still followed up in the clinic. Patients may have been treated in both the maxilla and the mandible or several times in one jaw. Data has been reported on patient and/or operation level, and statistically not independent implant-level data has been handled with caution.

## Results

Altogether, 2,431 patients provided with single-implant restorations were included in the database. Of these, 14 patients were excluded because they were from abroad, leaving 2,417 (26.5% of the total patient database). Many of the patients were aged 15 to 25 years (42.3%) (Fig 1) and mean age at first implant operation was  $36.3 \pm 18.75$  years (range: 13 to 89 years). In total, 1,241 of the treated patients were female (51.3%). Data on last visit to determine time of follow-up is missing for one patient, here recorded as lost to follow-up after crown placement.

Distributions of treated patients, performed operations, and placed implants are presented in Table 1. Included patients ( $n = 2,417$ ) were provided with 3,211 implants at 2,665 operations. Only one implant per operation was placed in 2,167 of these operations (81.3%). In the remaining operations, 238 patients were treated with more than one implant, 110 of them in both jaws. Of the operations, 31 were reentry operations in which lost single implants were replaced in the edentulous single-tooth site.

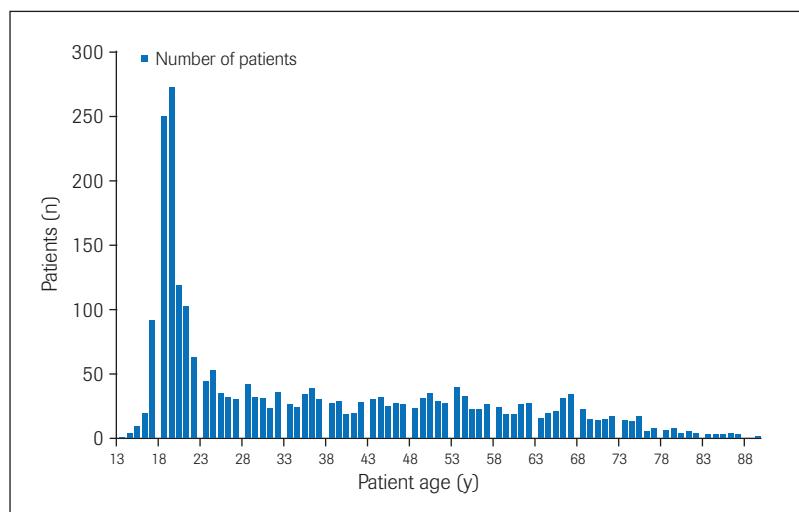
Patients provided with implants with turned surfaces in the maxilla or mandible were followed up for a maximum of 32 and 27 years, respectively. Corresponding maximum years of follow-up for patients with implants with moderately rough surfaces were 14 and 13 years, respectively. Distribution of total numbers of patients followed and lost to follow-up during the years is presented in Table 2. A small difference can be seen in distribution of patients lost to follow-up when data is reported for the entire group on patient or operation levels (Table 2). The proportion of the patients lost to follow-up progressively increased with time of follow-up (Table 2, Fig 2). In total, 1,185, 573, 231, 83, and 29 patients were followed up for at least 5, 10, 15, 20, and 25 years,



**Fig 1** Distribution of performed single-implant operations by year of surgery (1982–2013), jaw, and implant surface during inclusion.

**Table 1** Distribution of Consecutively Treated Single-Implant Patients, Performed Operations, and Placed Single-Crown Implants Provided with a Turned or a Moderately Rough Surface in Maxillae and Mandibles Between January 1982 and December 2013

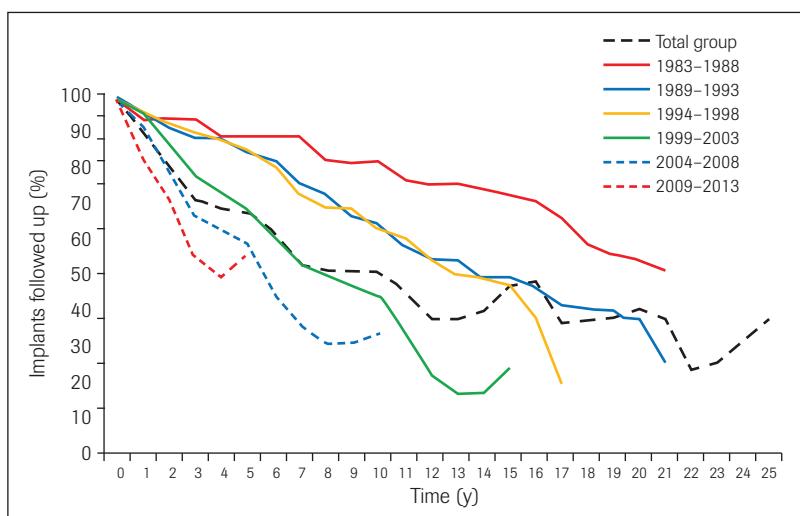
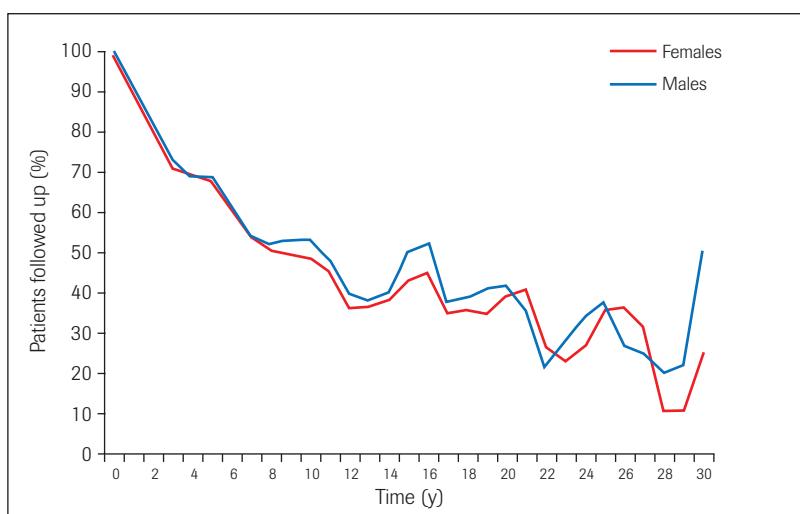
	Patients (n)	Operations (n)	Implants (n)
<b>Maxillae</b>			
Turned surface	757	794	960
Turned/moderately rough surface	4	4	4/3
Moderately rough surface	1,118	1,241	1,470
Maxillae total	1,879	2,039	2,437
<b>Mandibles</b>			
Turned surface	131	146	187
Turned/moderately rough surface	0	1	1/1
Moderately rough surface	408	479	581
Mandibles total	539	626	774
Total	2,417	2,665	3,211



**Fig 2** Distribution of patients by age from 1982 to 2013.

**Table 2** Distribution of Single-Implant Patients and Single-Implant Operations Still Participating in the Follow-Up Program at the Clinic at Different Time Periods

Follow-up (y)	Total group (%)		Patients followed up by time period (%)						
	Operations	Patients	1983–1988	1989–1993	1994–1998	1999–2003	2004–2008	2009–2013	
0 (Baseline)	2,665 (100)	2,417 (100)	66 (100)	107 (100)	224 (100)	609 (100)	588 (100)	823 (100)	
1	2,415 (90.6)	2,185 (90.4)	62 (93.9)	103 (96.3)	216 (96.4)	583 (95.7)	538 (91.5)	683 (83.0)	
5	1,295 (68.3)	1,185 (68.2)	59 (89.4)	91 (85.0)	192 (85.7)	415 (68.1)	347 (59.0)	81 (56.3)	
10	615 (50.7)	573 (50.9)	54 (81.8)	69 (64.5)	143 (63.8)	267 (43.8)	40 (33.6)		
15	242 (46.6)	231 (46.6)	48 (72.7)	53 (49.5)	106 (47.3)	24 (24.2)			
20	87 (41.2)	83 (40.7)	36 (54.5)	40 (37.4)	7 (22.6)				
25	29 (38.2)	27 (37.0)	26 (39.3)	1 (14.3)					
30	3 (37.5)	3 (37.5)	3 (37.5)						

**Fig 3** Percentage of single-implant patients followed up over 25 years in relation to total number of patients treated during different time periods. A minimum of 25 patients were included at the end of the survival curve.**Fig 4** Percentage of patients followed up over 30 years by gender.

respectively. A higher follow-up compliance was noticed for patients treated in the earlier period of inclusion (Table 2, Fig 3). No difference was found in follow-up comparing male and female patients (Fig 4), and no obvious difference was found in follow-up compliance among age groups during the first years of follow-up (Fig 5). However, for the later part of the follow-up period, the oldest group of patients showed an increased level of drop-out (Fig 5).

Altogether, 67 patients/operations were identified with 67 implant failures during follow-up, and no patient lost more than one implant (Table 3). A total of 58 patients lost implants at their first/only operation, while the remaining 9 patients had experienced more than one single-implant operation. Of the patients with failures, 34 were female (50.1%) and the mean age at first surgery was  $37.6 \pm 18.98$  years.

A majority of implant failures were reported during the first year of follow-up (83.6%) (Table 3), with only one implant failure between 5 and 10 years and no failures after 10 years. No patient lost an implant that was placed after implant failure (reentry operation). The overall proportion of failing implants was higher in mandibles ( $n = 19$ ; 3.5%) compared with maxillae ( $n = 48$ ; 2.6%) and in patients provided with implants with a turned ( $n = 39$ ; 4.4%)

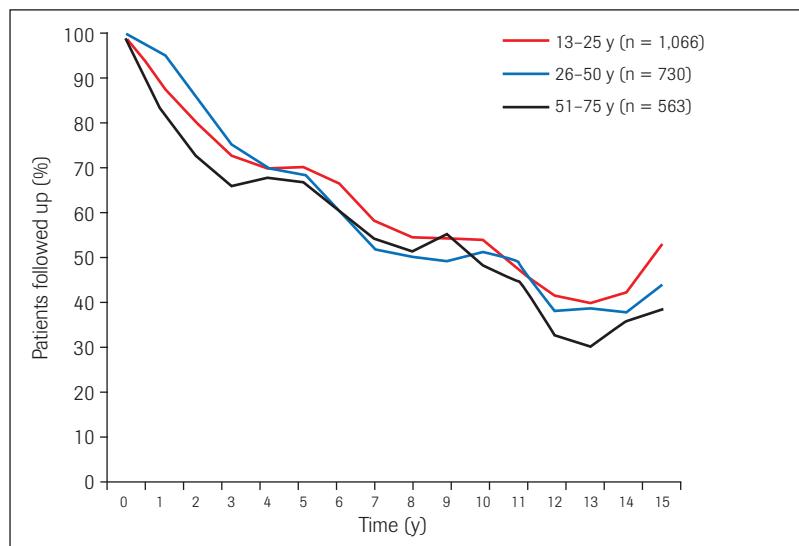
compared with a moderately rough surface ( $n = 28$ ; 1.8%).

Overall patient implant treatment CSR was 97.1% after 25 years of follow-up. Implant CSR was calculated to be 95.8% and 95.1% for operations placing implants with a turned surface in maxillae and mandibles after 25 and 15 years of follow-up, respectively (Fig 6). Corresponding CSRs for implants with a moderately rough surface were 98.5% and 97.2% after 11 years of follow-up, respectively (Fig 6). Reduction of survival rates following the first annual examination were within one percentage (0.00–0.96%) for all surfaces and jaws.

## Discussion

The present study was designed as a retrospective study<sup>14</sup> focusing on whether earlier published encouraging data on single-implant treatment<sup>4,5,7,9,12,13</sup> could be maintained in larger routine implant populations over longer periods (effectiveness) when using implants with different surfaces, or whether an obvious decrease in implant survival rate could be expected. Certainly, many more parameters regarding single-implant treatment could have been collected and would have improved the information and value for the clinician. However, this would also have been much more time consuming and could have jeopardized completion of the study. More data and information on the treatment outcome would probably have not affected the clinical key question, and the present results suggest a continuous stable and predictable survival of single implants in large populations, slightly better for moderately rough implant surfaces (Fig 6).

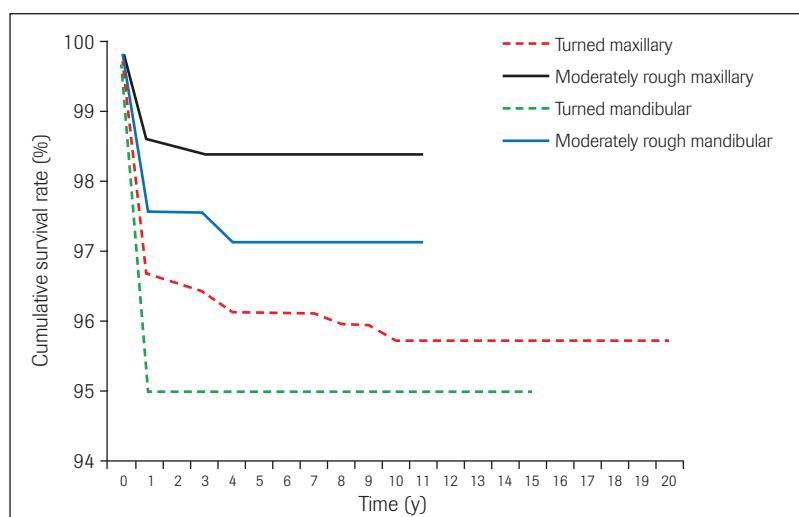
The general consensus in dentistry and medicine is that all treatment procedures should be based on clinical evidence, where much of the evidence is established from systematic reviews and meta-analyses covering publications identified from PubMed



**Fig 5** Percentage of patients followed up over 15 years by patient age at inclusion.

**Table 3** Distribution of Single Implant Failures by Jaw During Follow-Up

	Implants/operations (n)	
	Turned surface	Moderately rough surface
<b>Maxillae</b>		
Early failures (0–1 y)	25	14
Late failures (> 1–5 y)	5	2
Late failures (> 5–10 y)	2	0
<b>Mandibles</b>		
Early failures (0–1 y)	7	10
Late failures (> 1–5 y)	0	1
Late failures (> 5–10 y)	0	1
Total	39	28



**Fig 6** Up to 20-year cumulative survival rates for single-implant operations performed in maxillae and mandibles for implants with different surfaces. Calculations include at least 25 patients at termination.

searches and similar data sources.<sup>10,11,21</sup> Selected publications should be judged according to strict protocols set up before the inclusion phase, aiming to address different key factors before inclusion.<sup>10,11,21</sup> A common observation from these reviews is that most of the studies that show up on the first data list from the PubMed searches are excluded, and that eventually only a few manuscripts can be included in the review.<sup>10,11,21</sup> One of many reasons for exclusion of studies is that they focus more on the results than on describing inclusion procedures and patient data.<sup>22</sup>

The present study covers thousands of patients, operations, and implants included over a long period that comprises many methodologic challenges and problems. Certainly not all of these can be controlled in an optimal way, and therefore only two basic endpoints with low risk of misinterpretation have been used: implant failure and time of follow-up. Altogether, 2,417 patients were provided with single-implant restorations during inclusion (27%), where basically no patient was excluded from implant treatment. An earlier publication reported a decreasing number of implants per operation and a decrease in mean patient age during the years at the present clinic.<sup>15</sup> With fairly even numbers of operations performed over the years,<sup>15</sup> this means that single-implant treatment is more common today and that clinical experience has increased over time. Observed lower single-implant failure rates during the later period of inclusion and follow-up could be related to changed implant surface<sup>15</sup> (Fig 6), but increased overall experience in the clinic could also play a role even though the individual surgeon's learning curve has not been shown to be an important factor in the present clinic.<sup>23</sup>

Life tables and calculation of CSRs were introduced in the late 1950s to estimate patient survival when data was incomplete and some patients were lost to follow-up.<sup>20</sup> It must be assumed that it was never intended or even considered that persons recorded as failures (deceased) could also be represented as survivors in these estimations. This would be the case when using Kaplan-Meier calculations to follow up implant treatment on the implant level, covering patients restored with many implants where some are lost and some are still in function. Thus, when implant-level life tables are used in situations where patients are provided with many implants, the estimations become unpredictable because the observations are not independent from one another.<sup>24,25</sup> However, in the present study where numbers of patients ( $n = 2,427$ ) and operations ( $n = 2,665$ ) are comparable, results on proportions of followed-up patients and operations are comparable (Table 2). This may allow for operation-level instead of patient-level calculation of single-implant survivals (Fig 6)

without randomization of operations when implant failures are observed in one of several operations performed in the same patient.

Furthermore, Kaplan-Meier calculations are based on other assumptions, also relevant for the present study design. First, it is assumed that the survival prospects of patients/operations/implants that are lost to follow-up at any time should be the same as for those who continue to be followed.<sup>26</sup> It is also assumed that survival probabilities are independent of recruitment time and "that the event happens at the time specified."<sup>26</sup> This means that it is questionable from a scientific point of view to include patients/operations/implants with a documented difference in survival (ie, implant surface or treated jaw)<sup>15</sup> into the same life table. To compensate for this in the present study, separate life tables have been calculated for implants with different surfaces and for different jaws (Fig 6). Furthermore, patient compliance has been evaluated for different years of inclusion and age and gender of patients (Figs 3 to 5). Regarding the time when the event occurs and when it is observed, it is reasonable to assume that early implant failures are more easily noticed in the clinic while later failures may occur without being reported to the clinic, or that patients show up at a much later stage. A higher rate of complications has been reported for noncompliant as compared with compliant patients,<sup>27,28</sup> and it is reasonable to consider all life table calculations with caution, particularly regarding long-term observations of failure events.

Life table calculations become an estimate first when one or more patients are lost to follow-up.<sup>29</sup> In the present study it can be observed that many patients were lost to follow-up, a trend that became more pronounced the later the patients were included (Fig 3). Certainly, the larger the patient population and the longer the follow-up time, the higher the risk of losing patients to follow-up. In patient populations with a higher mean age at inclusion, 38% and 55% of deceased patients have been reported after 15 and 28 years, respectively.<sup>30</sup> In the present study, mean age at surgery was much lower but patient lifestyle and increased tendency to relocate at a young age may contribute to lower compliance in younger age groups as well. A changed logistic protocol in the present referral clinic with more prosthetic treatment performed by the referring dentists could further decrease patient compliance. It has been reported that patients who are treatment pioneers or who participate in small research groups show higher compliance than patients treated on a more routine basis.<sup>2,31-33</sup> The higher compliance for the earliest group of pioneer single-implant patients in the present study supports this assumption (Fig 3).

High or low levels of follow-up compliance could be used today as a measure for whether the treatment is special (efficacy) or routine (effectiveness) in a referral clinic and judged accordingly. These lower levels of compliance may be compensated for by including more patients so that greater numbers remain at termination of the study. Altogether, 573 patients were followed up for 10 years, which must be considered a high number since total number of patients available for meta-analyses earlier reached about 400 worldwide.<sup>10,11</sup>

Accordingly, when low failure levels are expected in a study it is important to include many patients to allow a reliable analysis of observed complications during follow-up. The present cut-off point for life table calculation was 25 patients, which is comparable with the numbers of patients included in studies with smaller populations. This threshold means that a theoretical late implant failure would increase the failure rate a maximum of 4%. Extending the life tables to the very last patient would increase the theoretical risk of a failure to reach 100% at the end, which is not recommended. This cut-off point should be set before the start of the study.

The present life tables show higher survival rates for implants provided with moderately rough surfaces compared with implants with a turned surface (Fig 6). This is in accordance with earlier studies showing lower failure rate for implants with a moderately rough surface.<sup>15,17-19</sup> Furthermore, data indicate that the failure rate is higher in mandibles as compared to maxillae, irrespective of the implant surface used (Fig 6), which is not in accordance with earlier clinical reports from the present clinic. In earlier studies on edentulous patients, higher failure rates are reported for maxillary implants compared with mandibular implants.<sup>2,15,17,18</sup> This difference may be related to the placement of single implants in the mandible in more demanding sites with higher loads in posterior regions, shorter implants, and lack of apical cortical support. Since most of the failures are observed early after surgery, this is more of a healing problem (establishing osseointegration) than a maintenance problem. Thus focus should be on how the implants are placed and loaded during the early phase. More one-stage surgical procedures performed in the mandible could also contribute to the difference in implant survival rate by jaw, which is especially pronounced during the early stage of healing and function.<sup>34</sup> However, considering the overall 10-year results for single-implant treatment, the present study compares well with earlier reviews<sup>10,11</sup> and indicates that single-implant treatment is a predictable option in somewhat longer time perspectives with no indication of increased failure rates in longer follow-up intervals.

## Conclusions

Within the limitations of the present study design, numbers of included/lost patients, and complexity of long-term routine population data, certain conclusions could be made. Altogether 573 patients were followed up for 10 years (50.9%), 231 for 15 years (46.6%), and 83 for 20 years (40.7%). Patient follow-up compliance was higher for those patients treated in the early period of inclusion (1982–1988). Of 2,417 patients (2,665 operations, 3,211 implants), 65 patients were recorded with an implant failure. No implant was reported as a failure after 10 years of follow-up. The overall 25-year CSR for single-implant operations was 97.1%. Differences in survival rates were observed between implants with different surfaces and different jaws during the early phase of treatment (establishment of osseointegration). No or only small changes in survival rates were observed for surfaces and jaws after first year of function (maintenance of osseointegration). The CSR for 25 and 15 years was 95.8% and 95.1%, respectively, for single-implant operations using implants with a turned surface in maxillae and mandibles. The 11-year CSR was 98.5% and 97.2%, respectively, for single-implant operations using implants with a moderately rough surface in maxillae and mandibles.

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# A New Fast and Simple Border Molding Process for Complete Dentures Using a Compound Stick Gun

Chan Park, DDS, MSD<sup>1</sup>/Hong-So Yang, DDS, PhD<sup>2</sup>/Hyun-Pil Lim, DDS, PhD<sup>3</sup>/Kwi-Dug Yun, DDS, PhD<sup>3</sup>/Gye-Jeong Oh, PhD<sup>4</sup>/Sang-Won Park, DDS, PhD<sup>2</sup>

This article describes the use of a newly invented compound stick gun to take impressions for complete denture. The border molding process involves loading the modeling compound in an electric heating device and applying an even thickness of compound on the flange of a custom tray at a proper temperature without hot water tempering. This method provides a quicker and easier border molding process alternative to conventional techniques. *Int J Prosthodont* 2016;29:559–560. doi: 10.11607/ijp.4891

The goal of impression taking is maximum possible extension over all tissue capable of supporting a denture while avoiding impinging on movable tissue during normal functional movement.<sup>1</sup> A commonly used method in complete denture impression taking is to fabricate a custom tray and apply impression compound in sections around the borders of the tray.

Impression compound is a thermoplastic material, and sticks are commonly used for border molding.<sup>2</sup> Modeling compound has a very low thermal conductivity and is acceptably soft between approximately 49°C (120°F) and 60°C (140°F). For the conventional border molding procedure, a direct flame is used for thorough softening. The compound sticks should be moved over the flame but should not be allowed to boil.<sup>3</sup> Once the compound is added to a flange area of the impression tray, the material is tempered in the hot water bath for approximately 5 to 8 seconds.<sup>1</sup> Immersion in a hot water bath provides an acceptable but minimal working time. Because of the minimal working time and difficult handling of modeling compound, it has been recommended that border molding using modeling compound be completed in multiple reasonably small areas.<sup>3</sup>

A compound stick gun is fabricated for an automatic, thorough heating of the compound. This device can apply the stick compound with suitable viscosity for border molding. It has several advantages compared with the multisectional procedure; for example, it is easy to apply an even 2- to 3-mm thickness of modeling compound on the buccal or lingual flange area of the custom tray at once. The hot water bath is not needed for tempering because the compound stick gun does not use direct flame, lengthening the working time. The border molding technique with stick compound saves time and equipment and is easy to learn. Repeated adding, tempering, and ice cooling of the compound is not required. If compound molded border areas need correction, border molding can be repeated following the conventional procedure. Because the gun has three temperature options (50°C, 60°C, and 70°C), doctors are able to use stick compounds from different companies.

An extended border of an impression tray may be molded at one time, as with heavy-bodied vinyl polysiloxane. Border molding in a jaw must usually be done twice because of the amount of compound in a stick: the buccal and labial border are molded at once with the posterior extent of the tray in the maxillary arch, followed by the buccal or labial border and lingual flange of the tray in the mandibular arch.

## Technique

A custom tray is first fabricated from a preliminary cast. Next, the modeling compound stick (Kerr) is inserted in the compound gun (HWDMGG-2013, Hummer) (Figs 1a and 1b). The electronic power on the gun is connected and the temperature selected (button 3, 70°C, is suitable for Kerr impression compound) (Fig 1c). When the red light stops flashing, the gun is sufficiently heated to discharge the melted modeling compound. The molten compound is then

<sup>1</sup>Graduate Student, Department of Prosthodontics, School of Dentistry, Chonnam National University, Gwangju, Korea.

<sup>2</sup>Professor, Department of Prosthodontics, School of Dentistry, Chonnam National University, Gwangju, Korea.

<sup>3</sup>Associate Professor, Department of Prosthodontics, School of Dentistry, Chonnam National University, Gwangju, Korea.

<sup>4</sup>Research Professor, RIS Foundation for Advanced Biomaterials, School of Dentistry, Chonnam National University, Buk-gu, Gwangju, Korea.

**Correspondence to:** Prof Sang-Won Park, Department of Prosthodontics, School of Dentistry, Chonnam National University, 33 Yongbong-ro, Buk-gu, Gwangju, 500-757, Korea.  
Fax: +82-62-530-5639. Email: psw320@jnu.ac.kr

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**Fig 1** Automatic compound stick gun. **(a)** External profile. **(b)** Insertion of modeling compound sticks. **(c)** Selection of a temperature option.



**Fig 2** An even thickness of 2 to 3 mm modeling compound is applied on all buccal flange areas of the custom tray at once. **(a)** Applying the molten stick impression compound to the buccal border of the tray. **(b)** Finished buccal border molding.



**Fig 3** Posterior extent of the border molding. **(a)** Applying stick impression compound to the custom tray. **(b)** Completed border molding.

applied on all of the buccal border of the custom tray with no hot water tempering needed (Figs 2a and 3a). Border molding for maxillary impression is completed in two procedures (Figs 2b and 3b).

### Conclusions

This technique using a new device can make the border-molding procedure faster and simpler. It provides comfort to the dentist and the patient.

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# Association Between Masticatory Function and Oral Health–Related Quality of Life in Partial Maxillectomy Patients

Mohamed Moustafa Said, BDS, MPhil<sup>1</sup>/Takafumi Otomaru, DDS, PhD<sup>2</sup>/  
Yiliyaer Aimaijiang, DDS<sup>3</sup>/Na Li, DDS, MDS<sup>1</sup>/Hisashi Taniguchi, DDS, PhD<sup>4</sup>

**Purpose:** The aim of this study was to investigate associations between objectively and subjectively measured masticatory function and oral health–related quality of life (OHRQoL) in partial maxillectomy patients wearing dentomaxillary prostheses. **Materials and Methods:** A sample of 32 consecutively treated patients who had undergone a partial maxillectomy were enrolled. Masticatory function was assessed using two objective measures and one subjective measure. The objective measures were masticatory performance (MP), which was estimated by measuring the glucose extracted from gummy jelly, and food mixing ability ( $a^*$ ), which was assessed using color-changeable chewing gum. The subjective measure was perceived chewing ability, rated as masticatory score (MS) based on the patient's responses to a food intake questionnaire. OHRQoL was assessed using the Geriatric Oral Health Assessment Index (GOHAI). Relationships between the masticatory function measures and OHRQoL were analyzed using Spearman rank correlation coefficient. **Results:** The correlation coefficients ( $r$ ) obtained were 0.57 ( $P = .001$ ) for MS and GOHAI, 0.247 ( $P = .173$ ) for MP and GOHAI,  $-0.173$  ( $P = .343$ ) for  $a^*$  and GOHAI, 0.517 ( $P = .002$ ) for MP and  $a^*$ , 0.199 ( $P = .257$ ) for MP and MS, and 0.019 ( $P = .919$ ) for  $a^*$  and MS. **Conclusion:** Subjective MS showed a significant positive correlation with GOHAI score, suggesting that perceived chewing ability could be an important factor in the estimation of OHRQoL in partial maxillectomy patients. *Int J Prosthodont* 2016;29:561–564. doi: 10.11607/jp.4852

Patients who undergo maxillectomy often complain of compromised mastication because they have lost both dentition and maxillary bone,<sup>1</sup> which adversely affects their quality of life.<sup>2</sup> Different methods have been used to assess patients' masticatory function. Objective assessments include using gummy jelly or color-changeable chewing gum,<sup>3,4</sup> while subjective assessment involves patient-perceived chewing ability using a food intake questionnaire.<sup>5</sup>

Oral health–related quality of life (OHRQoL) has been assessed using patient-based outcome measures such as the Oral Health Impact Profile (OHIP)<sup>6</sup> and the Geriatric Oral Health Assessment Index (GOHAI).<sup>7</sup> A strong correlation is reported between GOHAI and OHIP, but GOHAI is considered more convenient for detecting oral function impairment and evaluating dental care needs in elderly individuals.<sup>8,9</sup>

A significant association was also seen between the chewing ability index and OHRQoL in the general population.<sup>10</sup> Perceived chewing ability was closely associated with OHRQoL in partially dentate patients<sup>11</sup> and was reported to be a critical factor in the assessment of OHRQoL in patients with removable partial dentures.<sup>12</sup>

A similar correlation between OHRQoL and maxillectomy patients remains undetermined. Furthermore, since the surgical defect size and configuration can vary widely and greatly affect the masticatory function and OHRQoL,<sup>13–15</sup> the present study focused only on patients who had undergone partial maxillectomy. The null hypothesis of this study was that no relationships exist between objective and subjective measures of masticatory function and OHRQoL in partial maxillectomy patients wearing dentomaxillary prostheses.

<sup>1</sup>Graduate Student, Department of Maxillofacial Prosthetics, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan.

<sup>2</sup>Assistant Professor, Department of Maxillofacial Prosthetics, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan.

<sup>3</sup>Researcher, Department of Maxillofacial Prosthetics, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan.

<sup>4</sup>Professor and Head of Department of Maxillofacial Prosthetics, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan.

**Correspondence to:** Dr Takafumi Otomaru, Assistant Professor, Department of Maxillofacial Prosthetics, Graduate School, Tokyo Medical and Dental University (TMDU), 1-5-45, Yushima, Bunkyo-ku, Tokyo 113-8549, Japan. Fax: +81-3-5803-5556. Email: otomaru.mfp@tmd.ac.jp

**Table 1** Correlations Between the Assessed Measures

Measure	MP	a*	MS	GOHAI
MP				
a*	0.517*			
MS	0.199	0.019		
GOHAI	0.247	-0.173	0.57*	

\* $P < .05$  (Spearman rank test).

MP = masticatory performance; a\* = food mixing ability; MS = masticatory score; GOHAI = Geriatric Oral Health Assessment Index.

## Materials and Methods

This cross-sectional study was conducted at the Clinic of Maxillofacial Prosthetics of Tokyo Medical and Dental University (TMDU) Dental Hospital. The assessment was restricted to partial maxillectomy patients for oral cavity tumor, absence of surgical reconstruction for the defect area, and satisfaction with the currently worn intraoral prosthesis that had been used for at least 6 months. Patients were excluded from the study if they wore an implant-retained prosthesis, had an interval of less than 1 year since surgical resection, had undergone surgical resection involving the entire left or right maxilla or structures other than the alveolar maxilla and hard palate, or were unable to speak, read, or understand Japanese. The recruited convenience sample for the study comprised 32 consecutive patients (10 women and 22 men; 26 malignant tumors and 6 benign tumors; mean age: 62 years; age range: 20–86 years) who were enrolled between September 2014 and June 2015. The study protocol was approved by the Ethics Committee of TMDU (Approval No. 865). All participants provided written informed consent after receiving a written and verbal description of the study.

### Masticatory Performance

The masticatory performance (MP) test was performed using cylindrically shaped gummy jelly (GC).<sup>16</sup> Participants were instructed to chew the jelly for 20 seconds before rinsing their mouth with 10 mL distilled water and emptying the mouth of as much water and jelly as possible into a cup containing filter paper. The filtrate was collected and the concentration of the dissolved glucose was measured with a blood glucose meter (GS-1, GC).

### Food Mixing Ability

A chewing gum that progressively changes in color from yellowish-green to red as it is chewed (Xylitol,

Lotte) was used to assess food mixing ability.<sup>4</sup> The gum was collected immediately after the patient chewed it for 100 strokes and compressed to a thickness of 1.5 mm in a polyethylene film between glass plates. The color of the chewed gum was then measured through the polyethylene film using a colorimeter (CR-13, Konica-Minolta). The color was assessed in the CIE L\*a\*b\* color space, and the a\* value, which denotes redness, was determined.

### Perceived Chewing Ability

Patients used a food intake questionnaire to rate their own chewing ability.<sup>5,17</sup> The questionnaire consisted of 35 food items classified into 5 grades of 7 items each based on food hardness. The total scores for each of the 5 grades were summed to obtain a masticatory score (MS) from 0 to 100 points.

### OHRQoL

OHRQoL was assessed using the GOHAI questionnaire,<sup>18</sup> which comprises 12 items reflecting 3 hypothesized domains of the impact of oral disease: physical function, psychosocial function, and pain or discomfort. The 12 questions pertained to how often the patients experienced difficulties in the preceding 3 months, with a cumulative score ranging from 12 to 60 points. A higher GOHAI score indicates better OHRQoL.

### Statistical Analysis

Spearman correlation coefficients were used to investigate correlations between MP, a\*, MS, and GOHAI. SPSS 21.0 software was used, with the level of significance set at .05.

## Results

The median (25%, 75%) scores for MP, a\*, MS, and GOHAI were 163.5 (119, 211), 17.2 (11.5, 21.8), 69.5 (51.5, 88.7), and 47.5 (43.2, 54.7), respectively. The correlation coefficients ( $r$ ) were as follows: 0.57 ( $P = .001$ ) for MS and GOHAI, 0.247 ( $P = .173$ ) for MP and GOHAI, -0.173 ( $P = .343$ ) for a\* and GOHAI, 0.517 ( $P = .002$ ) for MP and a\*, 0.199 ( $P = .257$ ) for MP and MS, and 0.019 ( $P = .919$ ) for a\* and MS (Table 1).

## Discussion

Patients with partial maxillectomy showed acceptable values of masticatory function compared with the values reported previously for complete denture wearers.<sup>19–21</sup> This could be attributed to the ability of the partial maxillectomy patients to chew on the

nondefect side, which had sound teeth or sufficient residual bone to perform masticatory tests with an obturator in place without major difficulties. GOHAI scores of 38.7, 46.3, and 54.0 have been reported in edentulous patients, partially dentate patients, and patients with  $\geq 20$  teeth, respectively.<sup>18</sup> Thus, the GOHAI scores of the partial maxillectomy patients in the present study are comparable with those of partially dentate patients.

The present results showed a significant positive association between MS and GOHAI score but no significant associations between the objective masticatory function measures (MP and a\*) and GOHAI score. These findings imply that patients' perception of chewing ability, more so than masticatory performance or food mixing ability, has a substantial effect on OHRQoL in partial maxillectomy patients. Consequently, the null hypothesis is partially rejected.

A significant association between perceived chewing ability and OHRQoL was observed in this study, which is generally consistent with the findings of previous studies involving the elderly, partially dentate patients, and patients with removable partial dentures.<sup>10-12</sup> Chewing ability is associated with both oral health and general health status, since it affects nutritional intake.<sup>22</sup> OHRQoL in partial maxillectomy patients may be improved by increasing their dietary choices rather than by improving their food crushing or mixing ability after successful prosthetic rehabilitation. This approach also may positively influence the patients' psychologic function by enabling them to better participate in community and social activities.

This study also revealed a significant positive correlation between MP and a\*. The association between both measures may be attributed to other masticatory factors, such as the number of occlusal support units or posterior teeth, both of which have been identified as strong predictive factors for masticatory performance in maxillectomy patients.<sup>23</sup> Surprisingly, neither MP nor a\* showed any association with MS, indicating that objective masticatory function is not an indicator of perceived chewing ability in partial maxillectomy patients. This finding is not in agreement with that of a previous study that suggested a significant positive correlation between food mixing ability and perceived chewing ability in maxillectomy patients.<sup>24</sup> However, it included both partial and total maxillectomy patients, and patients' perceived chewing ability was evaluated using a different method from that used in the present study.

The association between masticatory function and OHRQoL should also be investigated for different maxillectomy extent, such as total or bilateral total maxillectomy, along with other factors such as age, sex, resection site, defect size and configuration, radiotherapy, and dental status.

## Conclusions

Of the three masticatory function measures used in this study, only the subjective measure of MS showed a significant positive correlation with GOHAI score. Therefore, perceived chewing ability may be an important factor for assessing OHRQoL in partial maxillectomy patients wearing dentomaxillary prostheses.

## Acknowledgments

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#### Literature Abstract

#### **Hemodynamic Changes Following Injection of Local Anesthetics with Different Concentrations of Epinephrine During Simple Tooth Extraction: A Prospective Randomized Clinical Trial**

This prospective randomized clinical trial studied the effects of varying concentrations of epinephrine on hemodynamic changes in blood pressure (BP), heart rate (HR), and oxygen saturation ( $\text{SpO}_2$ ) on healthy patients. In total, 120 patients were randomly assigned to 3 groups: group 1, lidocaine 2% with epinephrine 1:80,000 (L80); group 2: articaine 4% with epinephrine 1:100,000 (A100); and group 3: articaine 4% with epinephrine 1:200,000 (A200). Systolic blood pressure (SBP) was significantly increased after injection of L80 in group 1 and continued after extraction relative to the preinjection state. In group 2, SBP also significantly increased after injection of A100, then decreased after extraction. In group 3, SBP insignificantly decreased after injection of A200, then increased after extraction. A200 had a significantly lesser effect on SBP (before and after injection) than L80 and had the least effect on the other measured parameters. Other relevant findings of this study included a decrease in diastolic blood pressure (DBP) after LA in all three groups (significant only in L80), a decrease in  $\text{SpO}_2$  3 minutes after injection in all groups (significant only in A100), and a further decrease in  $\text{SpO}_2$  in all groups after extraction, except L80. HR significantly increased 3 minutes after local anesthetic injection and decreased 3 minutes after extraction in all groups. Notwithstanding the insignificant differences in DBP, HR and  $\text{SpO}_2$  after administration of anesthesia and after extraction among the three groups, the authors considered A200 safer than L80 or A100 as it was the least likely to cause hemodynamic changes (particularly SBP and HR). A200 was thus recommended for local anesthesia before teeth extraction in a normal patient.

**Abu-Mostafa N, Al-Showaikhat F, Al-Shubbar F, Al-Zawad K, Al-Zawad F.** *J Clin Exp Dent* 2015;7(4):e471–e476. **References:** 21.

**Reprints:** Nedal Abu-Mostafa, Riyadh Colleges of Dentistry and Pharmacy, Oral and Maxillofacial Surgery and Diagnostic Science Department, Dental Hospital (Namuthajia) Riyadh, Kingdom of Saudi Arabia. Email, nabumostafa@gmail.com —*Loke Weiqiang, Singapore*.

# Analysis of Endodontic Complications Following Fixed Prosthodontic Rehabilitation

Zeynep Uzgur, PhD, DDS<sup>1</sup>/Recep Uzgur, PhD, DDS<sup>1</sup>/Hakan Çolak, PhD, DDS<sup>1</sup>/Ertuğrul Ercan, PhD, DDS<sup>2</sup>/Mehmet Dallı, PhD, DDS<sup>3</sup>

**Purpose:** The aim of this study was to determine endodontic treatment needs and types of endodontic disease following fixed prosthodontic treatment 24 hours after tooth preparation, 1 week after tooth preparation, 1 month after placement, and 6 months after placement. **Materials and Methods:** Study groups consisted of patients who attended a university dental hospital department of prosthodontics for fixed prosthodontic treatment from January 2011 to December 2013. All teeth were clinically and radiographically evaluated according to American Association of Endodontists evaluation criteria before preparation. Metal-ceramic fixed partial dentures were placed for all patients. A total of 1,633 abutment teeth were prepared with 1,100 pontics in 524 patients (214 female and 310 male). Participant age, sex, and tooth number were recorded. Endodontic treatment follow-up was scheduled for 24 hours after tooth preparation, 1 week after preparation, 1 month after placement, and 6 months after placement, and all teeth were evaluated after placement of FPDs according to a modified criteria. **Results:** 2,733 retainers were placed with 624 FPDs. Of the FPDs, 332 (53%) were placed in the posterior and 196 (31.5%) in the anterior region. The remaining 96 FPDs (15.5%) were placed anteroposterior. The abutment/pontic ratio was 1.44:1. The number of retainers per FPD was 4.37. Of 1,633 abutment teeth, 103 were endodontically treated after placement of FPDs. Most observed endodontic disease was symptomatic irreversible pulpitis. There were statistically significant differences in terms of teeth regions ( $P < .001$ ). When follow-up times of 24 hours, 1 week, 1 month, and 6 months were evaluated, there was no statistically significant difference among all teeth groups ( $P > .05$ ). **Conclusion:** A total of 2,733 retainers on 624 FPDs were evaluated over 6 months, and the mean endodontic treatment need ratio was 6.3%. *Int J Prosthodont* 2016;29:565–569. doi: 10.11607/ijp.4601

In modern dentistry, the majority of operators use metal-ceramic fixed partial dentures (FPDs), which require between 1.0 and 1.5 mm of enamel to be removed from the axial/occlusal surface.<sup>1</sup> Although the significance of this is slight when ultraconservative preparation methods and a restorative process are used, indisputable threats to pulpal integrity exist during fixed prosthetic treatment.<sup>2</sup> It has been reported that operators have injured the dentin-pulp complex when performing procedures that involve fixed prosthodontics.<sup>3</sup> Existing research in this field has revealed that the way dentin pulp reacts to FPD preparation should be an area of major concern for individuals involved in restorative and prosthetic

dentistry, and studies indicate a positive correlation between the requirement for endodontic treatment and FPD preparation and procedures.<sup>4,5</sup>

In the event that the pulp is damaged or a patient experiences further complications after prosthetic treatment, endodontic treatment may be required. The need for such treatment can emerge during the preparation activity itself, immediately following the treatment, or even a long time later.<sup>2,4,6–14</sup>

The way the pulp of a tooth responds to a FPD is influenced by a number of factors. These include the amount of dentin removed from the tooth surface, the process by which the crown is prepared, the heat and friction generated during the stripping process, the nature of the cementation materials employed, the presence of bacterial infection, and the occurrence of chemical injury and/or excessive drying of dentin.<sup>1,8,15–19</sup>

Understanding the issues associated with treating and preventing pulp damage is of significant importance to operators. The aim of this study was to determine endodontic treatment needs after preparation, after temporary restoration placement, and after fixed prosthetic rehabilitation.

<sup>1</sup>Private Practice, Istanbul, Turkey.

<sup>2</sup>Professor, Kırıkkale University, Faculty of Dentistry, Department of Restorative Dentistry, Kırıkkale, Turkey.

<sup>3</sup>Associate Professor, Katip Çelebi University, Faculty of Dentistry, Department of Restorative Dentistry, İzmir, Turkey.

**Correspondence to:** Dr Recep Uzgur Zirve.

Email: ruzgur@gmail.com

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**Table 1** Endodontic Evaluation Criteria According to the American Association of Endodontists

Medical/dental history	Past/recent treatment, drugs
Chief complaint (if any)	How long, symptoms, duration of pain, location, onset, stimuli, relief, referred, medications
Clinical exam	Facial symmetry, sinus tract, soft tissue, periodontal status (probing, mobility), caries, restorations (defective, newly placed?)
Clinical testing: Pulp tests	Cold, electric pulp test, heat
Clinical testing: Periapical tests	Percussion, palpation, Tooth Slooth (biting)
Radiographic analysis	New periapicals (at least 2), bitewing
Additional tests	Transillumination, selective anesthesia, test cavity

**Table 2** Preparation Depth, Materials, and Equipment Used

Preparation depth	1.4 mm for axial; 2.0 mm for occlusal. <sup>23</sup> Deep cutter diamond was used to obtain the same depth.
Handpiece	300,000 rpm, <sup>21,22</sup> 2.2 bar, 16W, RM: standard 4-hole, triple spray, LED+ (W&H, Alegria)
Provisionals	Performed with indirect technique by the same dental technician, polymethyl methacrylate (Dentsply)
Cement (permanent)	Zinc polycarboxylate cement (SpofaDental, Adhesor Carbofine)
Cement (temporary)	TempBond Temporary Cement Type I (Kerr)
Metal alloy	Fabricated with casting technique and Co-Cr alloy were used (Remanium Star, Dentaurum)
Ceramco 3	Layering ceramic (Dentsply)

**Table 3** Control Procedures Used in this Study

<b>1. Patient recall</b>
<b>2. Chief complaint</b>
<b>3a. If yes</b>
1. Chief complaint history (how long, location, duration of pain, stimuli)
2. Clinical exam
a. Intraoral exam <ul style="list-style-type: none"> <li>▪ Soft tissue exam, periodontal exam, mobility, caries</li> </ul>
b. Extraoral exam <ul style="list-style-type: none"> <li>▪ Facial asymmetry</li> </ul>
3. Clinical tests (percussion, palpation, pulp tests)
4. Radiographic exam (periradicular, pulpal)
<b>3b. If no</b>
1. The integrity of the occlusal contact pattern (ascertained using articulating paper)
2. Signs of increased abutment mobility or sensitivity (ascertained by palpation, percussion, and directed air stream)
3. Signs of root cracks or fracture (ascertained by palpation, percussion, and periodontal probing and confirmed by radiographic examination)
4. Marginal integrity, including evidence of caries or loss of seal at the tooth-restoration interface (ascertained by probing and palpation)
5. Evidence of retreatment

## Materials and Methods

This study has been approved by the Ethics Committee of Dicle University Faculty of Medicine. The study group consisted of patients who attended the University Dental Hospital Department of Prosthodontics for fixed prosthodontic treatment between January 2011 and December 2013. Metal-ceramic retainers were used for all patients. Abutment teeth were selected that had not undergone any prior root canal and periodontal treatment. All teeth were clinically and radiographically evaluated before preparation according to American Association of Endodontists evaluation criteria (Table 1).<sup>20</sup>

The teeth were prepared using rotary cutting headpieces with the same rpm for all patients, and the clinician ensured that the underwater flow and air cooling speed were consistent across all treatments.<sup>21,22</sup> All teeth were prepared by the same operator to the same depth<sup>23</sup> using the same handpiece and new, sterilized diamond burs. The prepared teeth were restored with provisional FPDs until cementation of definitive restorations. Provisional restorations were constructed using polymethyl methacrylate (Dentsply), and all were performed by the same dental technician. Temporary restorations were cemented with temporary cement (TempBond Type I, Kerr).

The final metal-ceramic FPDs were cast with Co-Cr alloy (Remanium Star, Dentaurum) and layered with Ceramco 3 ceramic material (Dentsply) (Table 2). All metal-ceramic FPDs were placed and cemented with zinc polycarboxylate cement (SpofaDental, Adhesor Carbofine) after 1 week. Follow-up evaluations were performed 24 hours after tooth preparation, 1 week after preparation, 1 month after placement, and 6 months after placement. A modified control procedure<sup>13</sup> was used for the present study (Table 3).

In total, 1,633 abutment teeth were prepared with 1,100 pontics on 524 patients. A total of 2,733 retainers were placed with 624 FPDs. The age and sex of the participants were recorded (Table 4). The age of the patients ranged from 21 to 73 years, and there were 214 women and 310 men. The collected data were analyzed using Cochrane Q test for intragroup and chi-square test for intergroup comparison.

## Results

A total of 2,733 retainers were placed with 624 FPDs, of which 332 (53%) were placed in the posterior region of the jaws and 196 (31.5%) were

placed in the anterior region. The remaining 96 (15.5%) FPDs were positioned anteroposterior. The abutment-to-pontic ratio was 1.44:1. The number of crowns per FPD was 4.37. Of 1,633 abutment teeth, 103 were endodontically treated. Most treatment required was within 1 week for 40 abutment teeth, 24 hours for 26, 1 month for 20, and 6 months for 17. The region most likely to require endodontic treatment was the mandibular molars (7.43%). The maxillary premolars were least likely to require endodontic treatment, at 5.07% (Table 5).

In terms of endodontic diagnosis, symptomatic irreversible pulpitis, asymptomatic irreversible pulpitis, and pulp necrosis all occurred. The symptoms of symptomatic irreversible pulpitis were sharp pain on thermal stimulus, lingering pain, spontaneity (unprovoked pain), and referred pain. The pain may be accentuated by postural changes such as lying down or bending over. Diagnosis of asymptomatic irreversible pulpitis was based on subjective and objective findings indicating that the vital inflamed pulp was incapable of healing and that root canal treatment was indicated. Pulp necrosis was diagnosed when the pulp was nonresponsive to pulp testing and was asymptomatic. The most frequently seen endodontic diseases were symptomatic irreversible pulpitis (63.1%), asymptomatic irreversible pulpitis (19.4%), and pulp necrosis (17.5%) (Table 6).

In both jaws, the most frequently used abutment teeth were the maxillary second molars and the mandibular canines (Tables 7 and 8). The largest group by number of retainers was FPDs with three to five retainers, at 62% (Table 9). In all teeth groups, there were statistically significant differences in terms of follow-up intervals ( $P < .001$ ). When follow-up times of 24 hours, 1 week, 1 month, and 6 months were each evaluated, there was no statistically significant difference among all teeth groups ( $P > .05$ ).

## Discussion

This study evaluated the rate of endodontic complications after tooth preparation by follow-up time. The study group consisted of patients who had been admitted to the University Dental Hospital Department of Prosthodontics for fixed prosthetic rehabilitation. All patients were treated by the same operator and with a handpiece of the same speed. Clinical and laboratory procedures were standardized as much as possible to eliminate the effect of changes in operator and technician on the outcomes.

**Table 4** Patient Distribution by Age and Sex

Age (y)	Men (n)	Women (n)	Total (n)
21–35	53	44	97
36–55	179	109	288
56–73	78	61	139
Total	310	214	524

**Table 5** Tooth Areas and Number of Teeth Requiring Endodontic Treatment by Follow-up Time

Teeth region/type	n	Endodontically treated teeth (n [%])				<i>P*</i>
		24 h	1 wk	1 mo	6 mo	
Maxillary anterior	309	4 (1.29)	12 (3.88)	15 (4.85)	17 (5.50)	.001
Maxillary premolars	217	3 (1.38)	9 (4.15)	10 (4.61)	11 (5.07)	.001
Maxillary molars	316	5 (1.58)	14 (4.43)	20 (6.33)	23 (7.28)	.001
Mandibular anterior	325	5 (1.54)	11 (3.38)	16 (4.92)	21 (6.46)	.001
Mandibular premolars	197	3 (1.52)	7 (3.55)	8 (4.06)	11 (5.58)	.001
Mandibular molars	269	6 (2.33)	13 (4.83)	17 (6.32)	20 (7.43)	.001
	1,633	26	66	86	103	
	<i>P**</i>	.961	.916	.767	.816	

\*Cochrane Q test for intragroup comparison.

\*\*Chi-square test for intergroup comparison.

**Table 6** Endodontic Diagnosis by Follow-up Time

Pulp diagnosis	Follow-up time				Total (n [%])
	24 h (n)	1 wk (n)	1 mo (n)	6 mo (n)	
Symptomatic irreversible pulpitis	26	30	7	2	65 (63.1)
Asymptomatic irreversible pulpitis	0	6	8	6	20 (19.4)
Pulp necrosis	0	4	5	9	18 (17.5)
Total	26	40	20	17	103 (100)

**Table 7** Distribution of Abutments and Pontics in Maxillae

Teeth	Left		Right	
	Abutments	Pontics	Abutments	Pontics
Central incisors	45	39	39	31
Lateral incisors	43	51	35	23
Canines	76	37	71	33
First premolars	58	63	55	49
Second premolars	55	57	49	56
First molars	37	54	34	59
Second molars	102	37	91	45
Third molars	29	0	23	0
Total	445	338	397	296

**Table 8** Distribution of Abutments and Pontics in Mandibles

Teeth	Left		Right	
	Abutments	Pontics	Abutments	Pontics
Central incisors	38	39	46	42
Lateral incisors	34	28	34	30
Canines	86	19	87	6
First premolars	44	36	36	44
Second premolars	55	35	62	35
First molars	27	67	33	56
Second molars	79	14	76	15
Third molars	23	0	31	0
Total	386	238	405	228

**Table 9** FPDs by Number of Retainers

Retainers (n)	FPDs (n)	FPDs (%)
3–5	386	62
6–10	188	30
≥ 10	50	8
Total	624	100

**Table 10** Mean Results of Endodontic Complications After Preparation of Vital Tooth Abutments in Previous Studies from 1966 to Present

Authors	Vital abutments prepared (n)	Abutments requiring endodontic treatment after preparation (%)
Ericson et al <sup>14</sup>	668	2
Karlsson <sup>12</sup>	944	10
Cheung <sup>31</sup>	152	4.1
Jackson et al <sup>2</sup>	437	5.7
Valderhaug et al <sup>4</sup>	101	10
Walton <sup>13</sup>	688	2.7
Al-Khreisat <sup>32</sup>	616	6
Present study	1,633	6.3

All teeth were clinically and radiographically investigated before preparation. The teeth included in the study had not received any prior pulp treatment. Furthermore, the endodontic treatment needs of the patients involved in the study were determined according to the tooth condition as described by the patient, clinical signs and symptoms, and radiographic findings.<sup>20</sup> For the maxilla, 842 abutments and 634 pontics were used, for an abutment/pontic ratio of 1.32:1. For the mandible, 791 abutments and 466 pontics were used, with a higher abutment/pontic ratio of 1.69:1.

In the present study, 386 FPDs (62%) had 3 to 5 retainers, 188 FPDs (30%) had 6 to 10 retainers, and 50 FPDs (8%) had more than 10 retainers. According to these results, a high number of retainers is common.

This increases the risk of decay, endodontic therapy, plaque retention, and technical failures.<sup>24–27</sup> Use of implants is growing dramatically, especially for partial edentulism, decreasing the potential for biologic and technical complications.<sup>28,29</sup> However, a tooth-supported FPD has been the most common choice to replace missing teeth for the past six decades and remains so today. Every dentist is familiar with the procedure, and it is widely accepted by the profession, patients, and insurance companies.<sup>30</sup>

The present study was carried out in a public hospital. Unlike implant therapy, the FPD therapy was compensated by general public health insurance for patients. Due to the purpose of the study, only patients who were treated with FPDs were included.

Many important processes might contribute to pulpal death during the placement of FPDs. These include excessive tooth reduction, heat, handpiece vibration, pressure during tooth preparation, chemicals, and bacterial infection.<sup>1</sup> Since 1966, many studies have been performed on this subject. However, only a few long-term studies have examined the survival rates of teeth treated with FPDs (Table 10).

A published study using a roentgenographic technique found that 13 of 668 teeth exhibited periapical alteration after 1 year, and that there was no statistically significant difference among teeth. The mean endodontic treatment need rate was 2%.<sup>14</sup> A study at a prosthodontic special practice by Walton used an observation period of 5 to 10 years and found a mean endodontic treatment need rate of 2.7%.<sup>13</sup> In the present study, clinical and radiographic examinations were performed, and the mean endodontic treatment need rate was 6.22%. The differences in results for mean endodontic treatment requirements between these studies may be attributed to the examination technique used and the length of the observation period.

A study performed on FPDs constructed from porcelain-fused gold alloy 10 years after insertion found that the endodontic treatment need rate on vital abutments was 10%.<sup>12</sup> A further study performed for pulpal evaluation on teeth restored with FPDs showed that 25 of 437 vital teeth (5.7%) required root canal treatment after the restoration was cemented.<sup>2</sup> Although there are differences in follow-up times and type of materials used, the present results were similar to those outlined in these studies.

Cheung et al found that 4.1% of vital abutment teeth received endodontic treatment within 7 years.<sup>9</sup> These results are better than those found in the present study, but the observation period is much longer. A different study that examined early endodontic complications following FPDs found that the early endodontic complication rate was 6% after final cementation. In order of prevalence, mandibular molars,

maxillary molars, and mandibular anterior teeth were most commonly used as abutment teeth.<sup>10</sup> The endodontic complication rate and abutment teeth most frequently used were similar to those identified in the present study. By contrast, Raustia et al found that the teeth most commonly used as abutments were canines, maxillary molars, and then mandibular molars.<sup>6</sup>

Existing literature and research in this area indicates that a number of precautions should be taken during treatment procedures to reduce the risk of pulp damage. The operator should ensure that the provisional fits well and the crown is cemented in place as soon as possible. Once the superficial layer is removed, the dentinal surface should be adequately treated with antibacterial solution, thoroughly cleaned, and covered with a liner until final cementation. It is important that the dentin area is kept moist until the final cementation of the crown.<sup>8</sup>

## Conclusions

Around 6.3% of abutment teeth required endodontic treatment during the first 6 months. It is difficult to determine which clinical factor is most important in avoiding endodontic complications, but all factors mentioned need to be considered while placing FPDs.

## Acknowledgments

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# Using a Modified Neutral Zone Technique to Improve the Stability of Mandibular Complete Dentures: A Prospective Clinical Study

Peter Rehmann, PD Dr Med Dent<sup>1</sup>/Anna Katharina Künkel, Dr Med Dent<sup>2</sup>/Daniel Weber, Dr Med Dent<sup>3</sup>/Ulrich Lotzmann, Prof Dr Med Dent<sup>4</sup>/Bernd Wöstmann, Prof Dr Med Dent<sup>5</sup>

**Purpose:** The aim of this study was to evaluate the improvement in mandibular complete dentures (MCD) stability using a modified neutral zone technique (MNZT). **Materials and Methods:**

For 21 patients who were dissatisfied with their primary MCD, MCDs were fabricated using the MNZT. **Results:** Nearly all of the patients showed considerable improvement in oral health-related quality of life, and 85.7% of the patients stated an improvement in general denture stability and while chewing. A masticatory function test showed no significant changes. **Conclusion:** This MNZT seems to improve MCD function, especially in patients who cannot be treated with implants. *Int J Prosthodont* 2016;29:570–572. doi: 10.11607/ijp.4780

Treatment with complete dentures (CDs) in patients with atrophic mandibles remains a challenge in prosthodontics, especially in situations where implant treatment is not an option. In such cases, CDs must be predominantly stabilized muscularly in an area called the neutral zone (NZ), where the teeth are located in a balance between the muscular systems of the tongue and the cheek.<sup>1</sup> This concept has been an integral part of routine prosthodontic teaching for many years.<sup>2</sup>

In 2012, the present authors described a way to locate this NZ using a long-term impression technique.<sup>1</sup> Because of the small number of patients included in that study ( $n = 5$ ), statistical analysis was then waived. Due to the positive results of this pilot study, the modified neutral zone technique (MNZT) was established as a regular treatment protocol in the department in critical cases. To further evaluate the improvement in dentures stability using this technique, a prospective clinical study was conducted.

## Materials and Methods

For 6 months (February 2013 to July 2013), all completely edentulous patients with a severely resorbed mandible who complained about their mandibular complete denture (MCD) and for whom implant treatment was not an option for different reasons (eg, long-term bisphosphonate therapy, financial constraints) were selected ( $n = 22$ ).

Patients addicted to alcohol and/or drugs; suffering from malignant tumors, infectious diseases, or neurologic disorders (severe dementia); undergoing radiation therapy; or unwilling or incapable of consenting were excluded ( $n = 1$ ). The remaining 21 patients (10 women, 11 men; mean age  $71 \pm 19$  years) agreed to participate in the study. The patients reported an average longevity of edentulism of  $8 \pm 5$  years. Informed consent was obtained from all participants in writing. All patients were treated by the same dentist (A.K.K.) in the Department of Prosthodontics of the Justus-Liebig-University in Giessen, Germany. The study was completed in April 2014. No patients were lost to follow-up. All 21 patients had previously been provided with a new conventional CD that did not prove satisfactory. A MCD was fabricated for each patient using the MNZT described in 2012.<sup>1</sup> Before and after treatment, patient satisfaction and denture function were evaluated using the German short form of the oral health impact profile (OHIP-G14) and a masticatory function test.<sup>3</sup> After 4 weeks, all patients were asked to rate the improvement in denture stability in general, while speaking, and while chewing. For statistical analysis, sign test was used.

The study was approved by the Ethics Committee of the Justus-Liebig-University, Giessen, Germany (Reg No. 162/11) and registered in the German Clinical

<sup>1</sup>Assistant Professor, Department of Prosthodontics, Dental Clinic, Justus-Liebig-University, Giessen, Germany.

<sup>2</sup>Assistant, Department of Prosthodontics, Dental Clinic, Justus-Liebig-University, Giessen, Germany.

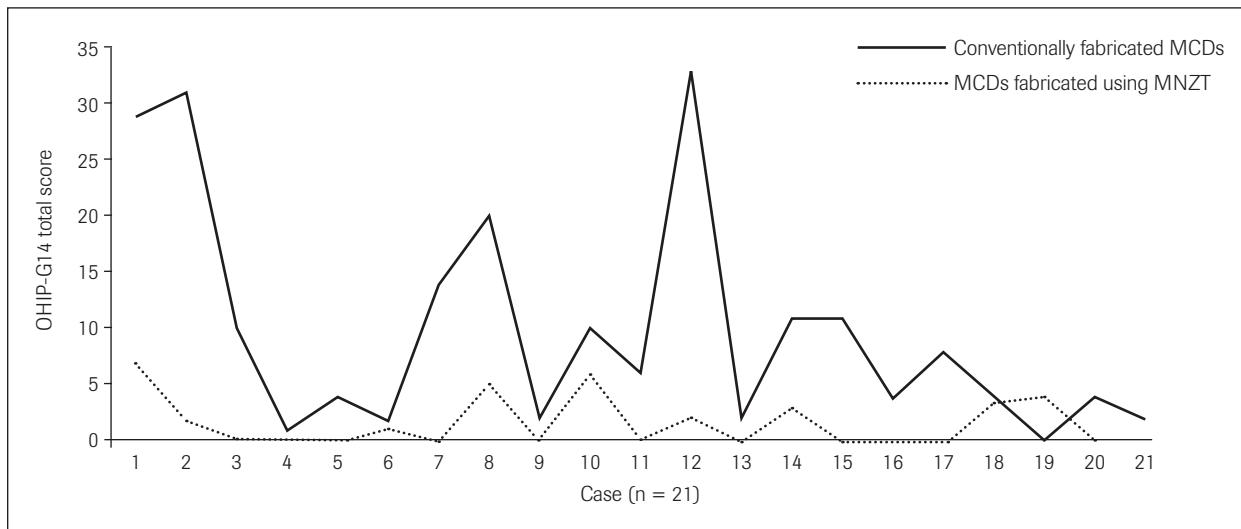
<sup>3</sup>Assistant Professor, Department of Orofacial Prosthodontics and Craniomandibular Function, Dental School, Philipps-University, Marburg, Germany.

<sup>4</sup>Professor and Chairman, Department of Orofacial Prosthodontics and Craniomandibular Function, Dental School, Philipps-University, Marburg, Germany.

<sup>5</sup>Professor and Chairman, Department of Prosthodontics, Dental Clinic, Justus-Liebig-University, Giessen, Germany.

**Correspondence to:** PD Dr Peter Rehmann, Department of Prosthodontics, Dental Clinic, Justus-Liebig-University, Schlangenzahl 14, 35392 Giessen, Germany. Fax: +49 641 99 46 139. Email: peter.rehmann@dentist.med.uni-giessen.de

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**Fig 1** Oral health-related quality of life assessment using OHIP-G14.

Trials Register (DRKS-ID: DRKS00003200; Universal Trial Number: U1111-1122-9976).

## Results

Nearly all of the patients showed a significant improvement in oral health-related quality of life (OHRQoL) based on the results of the OHIP-G14 evaluation (median OHIP score = 6 [compared to 0];  $P < .001$ ) (Figs 1 and 2), whereby higher overall OHIP scores imply a lower level of OHRQoL.

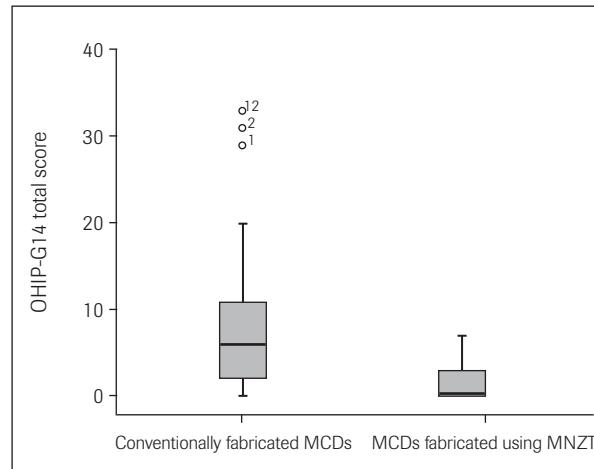
The masticatory function test showed no significant changes ( $P > .05$ ) in chewing ability (Fig 3). However, from a subjective point of view, 85.7% ( $n = 18$ ) of the patients stated an improvement in denture stability while chewing (Fig 4).

Additionally, 85.7% ( $n = 18$ ) of the patients reported an improvement in general denture stability and 14 patients (66.7%) reported an improvement while speaking. Prosthesis stability did not deteriorate for any patient (Fig 4).

No gender difference was observed for any of the variables investigated ( $P > .05$ ).

## Discussion

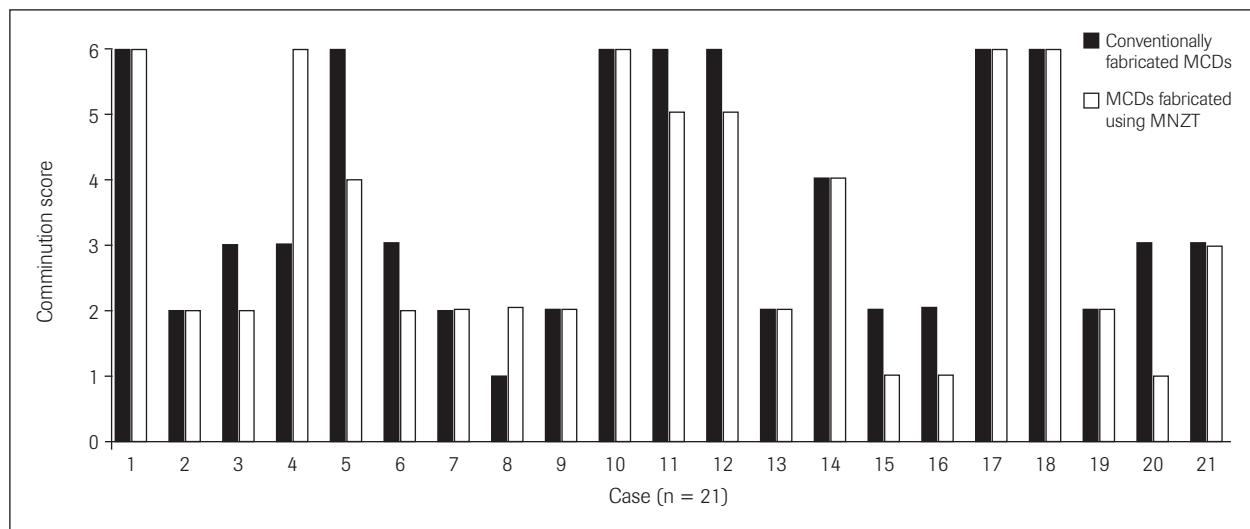
Komagamine et al<sup>4</sup> investigated how the individual factors of a subjective assessment of CDs by patients are connected to their OHRQoLs. Following the treatment of 93 patients with new CDs, the authors observed that improved denture stability in the mandible leads to an improvement in the OHRQoL. This observation is confirmed by conclusions by Langer et al,<sup>5</sup> that the satisfaction of people with CDs coincides with the function of the MCD, and by the present study.



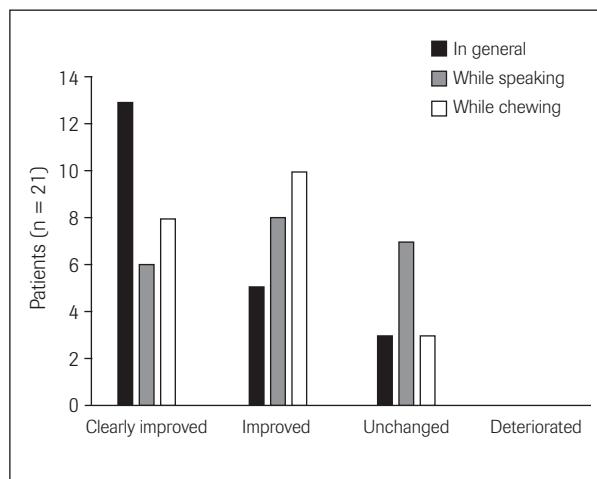
**Fig 2** OHIP-G14 total scores with both types of MCD presented in box plot.

Furthermore, the authors claimed a significant connection exists between the general satisfaction of a patient and masticatory function as subjectively perceived by the patient.

Also with regard to masticatory function, distinct connections could be found in the study presented here. Although no significant improvement in masticatory function could be determined via the masticatory function test, the treatment with MCDs fabricated using the MNZT still lead to a subjectively perceived improvement in denture stability while chewing by the patient. In contrast, Fahmy and Kharat<sup>6</sup> observed that an objective assessment of masticatory function rendered significantly better results with conventionally



**Fig 3** Masticatory function test before and after treatment.



**Fig 4** Patient assessment of denture stability after treatment.

fabricated MCDs. Nevertheless, the subjective assessment of the dentures by the patients showed a clear preference for the MCDs fabricated using a MNZT. The subjectively perceived comfort of the denture and the patients' well-being with regard to their masticatory function seem to outweigh the objectively measured masticatory function when assessing the dentures.

The design of the current study did not include a control group. It might be argued that the results present a distorted situation based on a desired answer pattern. In this context, one cannot rule out that patients might be urged, due to having been fitted with new dentures, to assess denture function and the OHRQoL more favorably than they would have done for their primary dentures.

## Conclusions

Despite its complexity, the MNZT can be recommended as a routine treatment option. It is a good way to improve the function of mandibular dentures and enhance patients' OHRQoL in cases where implant treatment is not an option.

## Acknowledgments

The authors reported no conflicts of interest related to this study.

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# The Relationship of Mandibular Morphology with Residual Ridge Resorption Associated with Implant-Retained Overdentures

Rohana Ahmad, BDS, MSD, PhD<sup>1</sup>/Mohamed I. Abu-Hassan, BDS, MDSc, PhD<sup>2</sup>/  
Junning Chen, BEng, PhD<sup>3</sup>/Qing Li, BE, ME, PhD<sup>4</sup>/Michael V. Swain, BSc Hons, PhD<sup>5</sup>

**Purpose:** The objective of this clinical study was to determine the relationship of mandibular morphology with residual ridge resorption (RRR) of implant-retained overdenture (IRO) patients.

**Materials and Methods:** RRR was quantified as change in bone volume over 1- and 2-year periods using cone beam computed tomography and a medical imaging program. Features of the mandibular morphology, namely the gonial angle, ramus length, ramus width, corpus length, and corpus height, were measured on three-dimensional models and correlated to the RRR. A total of 25 participants were treated with mandibular IROs opposing maxillary complete dentures. By the 2-year follow-up, radiographic data for 18 patients were complete for analysis. Of these 18 participants, half fall into the low gonial angle category and the other half into the high angle.

**Results:** The extent of RRR was highly variable among participants and ranged from -2 to +2 mm in depth over the 2-year period. The mean decrease in bone volume after the first year was  $3.8 \pm 4.5\%$ . This rate decreased to  $3.2 \pm 4.1\%$  after the second year. RRR occurs either by translation of the entire thickness of cortical layer apically or by thinning of the outer cortical layer. RRR was significantly correlated to gonial angle ( $r = .471; P = .048$ ) and predominantly occurred in the molar region in low-angle participants and more anteriorly in high-angle participants. There was no association between RRR and ramus length ( $r = -.341; P = .166$ ), ramus width ( $r = -.183; P = .468$ ), corpus length ( $r = .057; P = .821$ ), and corpus height ( $r = .097; P = .702$ ). **Conclusion:** Within the limitations of this study, it may be concluded that gonial angle is significantly related to RRR associated with IROs. *Int J Prosthodont* 2016;29:573–580. doi: 10.11607/jp.4726

The influence of mandibular morphologic features such as gonial angle, ramus length, ramus width, corpus length, and corpus height on residual ridge resorption (RRR) has received limited attention in the literature on removable conventional or implant prostheses. The most commonly cited report on gonial angle was published by Tallgren in 1970 and showed a significant association of gonial angle with RRR in

complete denture patients after 7 years.<sup>1</sup> Patients with a low gonial angle suffered significantly more RRR than those with a high gonial angle. Dipietro and Moergeli<sup>2</sup> and Mercier and Lafontant<sup>3</sup> also studied the mandibular morphology and its relationship with RRR in complete denture patients and concluded that gonial angle plays a significant role in RRR.

This topic is worth revisiting as severe ridge resorption has been reported in association with implant-retained overdentures (IROs).<sup>4–8</sup> This phenomenon has been attributed to several factors, namely the higher bite force associated with IROs,<sup>9</sup> the higher contact deformation exerted by this type of prosthesis,<sup>10</sup> and the concentration of forces induced by this type of prosthesis on the posterior region of the mandible due to the cantilever effect.<sup>11</sup> All these factors contribute to severe compression of the soft tissue mucosa under the IRO and affect the blood flow that supplies nutrients to and removes metabolites from the bone, potentially leading to increased resorption.<sup>12,13</sup> As most denture wearers are in their late middle age, the blood supply to the mandible predominantly comes from the subperiosteal plexus of vessels and is thus vulnerable to reduced circulation under denture pressure.<sup>14</sup> The blood pressure in the venous

<sup>1</sup>Associate Professor, Unit of Prosthodontics, Centre of Studies for Restorative Dentistry, Faculty of Dentistry, Universiti Teknologi MARA; Integrative Pharmacogenomics Institute (iPROMISE), Puncak Alam, Malaysia.

<sup>2</sup>Professor, Faculty of Dentistry, Universiti Teknologi MARA, Shah Alam, Malaysia.

<sup>3</sup>Postdoctoral Research Fellow, School of Aerospace, Mechanical and Mechatronic Engineering, University of Sydney, Sydney, Australia.

<sup>4</sup>Professor, School of Aerospace, Mechanical and Mechatronic Engineering, University of Sydney, Sydney, Australia.

<sup>5</sup>Professor, Faculty of Dentistry, University of Sydney, Sydney, Australia.

**Correspondence to:** Dr Rohana Ahmad, Unit of Prosthodontics, Centre of Studies for Restorative Dentistry, Faculty of Dentistry, Universiti Teknologi MARA, Sg Buloh, 47000 Selangor, Malaysia. Fax: 603-61266103. Email: drrohana@salam.uitm.edu.my

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capillary is quite low, ranging from 15 (venous) to 35 mmHg (arterial), equivalent to 2.0 to 4.7 kPa.<sup>15</sup>

Chen et al<sup>11</sup> have also shown that hydrostatic pressure generated in the soft tissue mucosa during function was a major biomechanical determinant accounting for RRR under the denture. It is not clear, however, whether gonial angle and other morphologic features have any influence on these factors. The gonial angle effect may be magnified in IROs compared with the conventional complete denture situation, where the bite force is much lower and the pressure is more uniformly distributed over a larger denture-bearing area.

The interactions between the size of the gonial angle (formed by the junction of the posterior and lower borders of the mandible) and the strength of the elevator muscles inserted into it have been widely documented, as have their orofacial manifestations. Individuals with low gonial angles have been shown to have a higher bite force and larger masseter muscles.<sup>16-21</sup> The angulations of the masseter have been reported to be more anteriorly inclined relative to the occlusal plane in individuals with high gonial angles, and more vertical in individuals with low gonial angles.<sup>22</sup> Consequently, the masseter mechanical advantage was found to be inversely related to the gonial angle.<sup>23</sup>

Therefore, the present study was designed to achieve two objectives: (1) to quantify RRR beneath implant-retained overdentures using a novel three-dimensional (3D) computational technique that allows precise identification of the areas of RRR and visually demonstrates the changes in bone contour, and (2) to determine if mandibular morphology, specifically gonial angle, ramus length, ramus width, corpus length, and corpus height, have any significant relationship with RRR.

It was hypothesized that the gonial angle, which has a direct influence on the masseter, will have a significant relationship with RRR magnitude and pattern in patients with IROs.

## Materials and Methods

### Participant Recruitment

A total of 35 participants were recruited for this study, but only 25 underwent the complete treatment protocol for IROs. Of these 25 complete subjects, 11 were men and 14 were women. They were aged between 52 and 79 years old at recruitment, with an average age of 67 years. Of the participants, four men who had cone beam computed tomography (CBCT) imaging done for implant planning later refused implant surgery and settled for complete dentures. The age range

of this group was 54 to 70 years, with an average age of 64 years. All participants had been edentulous in the mandible for at least 5 years. They were informed of the study protocol, which included making new dentures, implant surgery, yearly recalls, and three exposures to CBCT at yearly intervals (before treatment ( $T_1$ ) and at 1 ( $T_2$ ) and 2 years ( $T_3$ ) post-treatment, and gave their written consent to participate. The first CBCT was for implant planning and served as the baseline measurement of bone level, while the second and third imagings were for the evaluation of RRR. Exclusion criteria included any medical condition contraindicating implant surgery, irradiated or bone-grafted jaws, and tooth extraction within the last 6 months. Ethical approvals to carry out this study were obtained from the Ethics Committee of Universiti Teknologi MARA (UiTM), Malaysia (600-RMI [5/1/6], April 20, 2009, and 600-RMI [5/1/6/01] December 6, 2011). The first ethical approval was for the conduct of the study and the taking of CBCT scans at  $T_1$  and  $T_2$ . The second ethical approval was for the CBCT scan at  $T_3$  for overdenture participants and one repeat CBCT after a year for the four complete denture participants who had had the first CBCT taken.

### Clinical Study Protocol

Each participant had new maxillary and mandibular complete dentures fabricated with balanced occlusion using 30-degree Pilkington-Turner teeth (Bioform, Dentsply). Condylar guidance angles were recorded with a protrusive record and transferred to a semiadjustable articulator. These dentures were worn for at least a month to allow any denture complaints to be resolved before implants were placed. All clinical work was done by one prosthodontist (R.A.) and all laboratory work was carried out by one dental technologist.

CBCT images were taken with one machine (i-CAT, Imaging Sciences International). Imaging parameters were set at 120 kVp, 18.45 mAs, 20-second acquisition time, 13-cm field of view, and a voxel size of 0.30 mm. The effective radiation dose the patient received was 101.5  $\mu$ Sv. To help these edentulous patients remain stationary during scanning, they were asked to wear their dentures and bite gently in occlusion, and their heads were strapped to the head positioner in the x-ray machine. The DICOM files of the images were acquired and stored to a portable hard drive.

A two-stage surgical approach under local anesthesia was followed in implant surgery. SIMPLANT program (Materialise) was used to guide implant placement in the two canine regions. All participants received Ankylos implants (Dentsply). Immediately after surgery, the mandibular denture of each participant

was modified and relined with a soft tissue conditioner (Visco-gel, Dentsply). The implants were surgically uncovered after a healing period of 2 to 3 months, and Ankylos SynCone (Dentsply) abutments were used. The SynCone abutment consists of two cones. The first cone is angled and is connected to the implant. This connection allows 360-degree angular rotation to achieve a common path of insertion for the two abutments used for the overdenture. The second opposed cone serves as a prefabricated primary crown to anchor the denture, and it is incorporated into the intaglio surface of the denture. The overdenture was made so that it was mainly mucosa-borne by maximizing the coverage of the denture-bearing area. The participants were placed on an annual maintenance recall program.

### **Quantification of RRR**

The details of the technique used to quantify RRR have been described in an earlier publication.<sup>4</sup> Briefly, 3D models at the three time points were reconstructed and superimposed in Mimics version 14.1 (Materialise). The superimposed models were then exported into 3-matics version 5.1 (Materialise) to produce color maps that reveal the predominant areas of RRR that have occurred after 1 and 2 years. RRR results were quantified by measuring the changes in bone volume between the pre- and post-treatment models. The region of interest was from approximately 5 mm distal to the implants (to minimize the effects of radiation scatter from the implants) up to the retromolar area just anterior to the ascending ramus.

### **Measurement of Mandibular Morphology**

Gonial angle, ramus length, ramus width, corpus length, and corpus height were measured from the 3D reconstructed model in Mimics (Fig 1). A line was drawn tangential to the posterior borders of the ramus and the condyle, and another line tangential to the most inferior points at the gonial angle and the lower border of the mandibular body. The intersection of these two lines formed the gonial angle. As Mimics only allow lines to be drawn from selected points on the model, the line tangential to the most inferior points at the gonial angle and lower border of mandible has to be drawn on the mandible rather than on its lower border. Ramus length was measured from the highest point of the head of the condyle to the lowest point on the posterior border of the mandible.<sup>24</sup> Ramus width is the distance between the deepest point on the anterior border of the ramus and the posterior border of the ramus.<sup>24</sup> Corpus length is the distance from the pogonion to the lowest posterior



**Fig 1** Measurements of mandibular morphology. **(A)** Gonial angle. **(B)** Ramus height. **(C)** Ramus width. **(D)** Corpus length. **(E)** Corpus height.

point on the posterior border of the ramus. Corpus height is the vertical distance from the alveolar crest to the lower border of the mandible at the mental foramen.<sup>25</sup> Measurements were done on both the left and right sides of the mandible. However, as statistical tests revealed that there was no significant difference between left and right measurements, the measurements of the right side were used for subsequent analysis. To ensure intraobserver agreement, all measurements were taken by one researcher and repeated after a lapse of 4 weeks. Using SPSS version 20 (IBM), reliability analysis was done to calculate the intraclass correlation of the intraobserver reliability. Two-way mixed model and absolute agreement type were used for the analysis.

### **Statistical Analysis**

Data were analyzed using SPSS version 20. The intraclass correlation coefficients (ICC) were used to assess the intraobserver reliability in the morphologic features measurements. Univariate analysis was done to assess the effect of participants' demographic factors (eg, age and sex) on RRR. The association between RRR and mandibular morphology was examined using Pearson product-moment correlation coefficient. Correlations were considered statistically significant when  $P < .05$ . Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity, and homoscedasticity.

**Table 1** Measurements and Total RRR After 2 Years

Participant	Gonial angle (degrees) and classification (low/high)	Ramus length (mm)	Ramus width (mm)	Corpus length (mm)	Corpus height (mm)	RRR (%)
1	113.70 (low)	57.02	33.93	89.80	17.80	-13.3
2	116.90 (low)	55.34	33.18	90.00	25.50	-7.0
3	117.30 (low)	61.63	34.70	81.30	24.80	-11.7
4	119.40 (low)	62.19	36.98	96.90	19.80	-8.0
5	120.50 (low)	58.14	29.29	89.40	28.20	-10.3
6	128.20 (low)	50.92	27.02	82.90	19.50	-6.2
7	128.50 (low)	51.20	28.16	81.70	22.90	-14.3
8	129.10 (low)	56.69	31.83	89.40	19.20	-9.6
9	129.21 (low)	51.11	28.46	82.60	19.40	-23.0
10	133.10 (high)	53.48	31.09	81.30	20.20	-13.3
11	133.30 (high)	61.04	33.61	94.50	29.60	-8.2
12	133.36 (high)	42.72	30.00	89.40	19.20	-4.3
13	135.07 (high)	56.20	31.22	84.60	20.20	-2.3
14	135.90 (high)	42.07	30.75	90.50	21.90	3.3
15	136.90 (high)	49.20	26.61	76.40	25.50	-4.4
16	136.95 (high)	49.98	31.21	87.10	25.30	4.2
17	137.40 (high)	55.00	26.52	83.90	17.70	5.6
18	141.30 (high)	54.21	29.03	76.90	28.50	-3.3
Mean	129.23	53.79	30.76	86.03	22.62	-7.0
SD	8.29	5.69	2.94	5.65	3.82	7.16
SE	1.97	0.94	0.69	1.33	0.90	1.69
Maximum	141.30	62.19	36.98	96.90	29.60	5.60
Minimum	113.70	42.07	26.52	76.40	17.70	-23.00

**Table 2** Pearson Product-Moment Correlations Between RRR and Gonial Angle, Ramus Length, Ramus Width, Corpus Length, and Corpus Height

	RRR	Gonial angle	Ramus length	Ramus width	Corpus length	Corpus height
Pearson correlation	1	.471*	-.341	-.183	.057	.097
P		.048	.166	.468	.821	.702
Patients (n)	18	18	18	18	18	18

\*Correlation is significant at  $P = .05$  level (2-tailed).

## Results

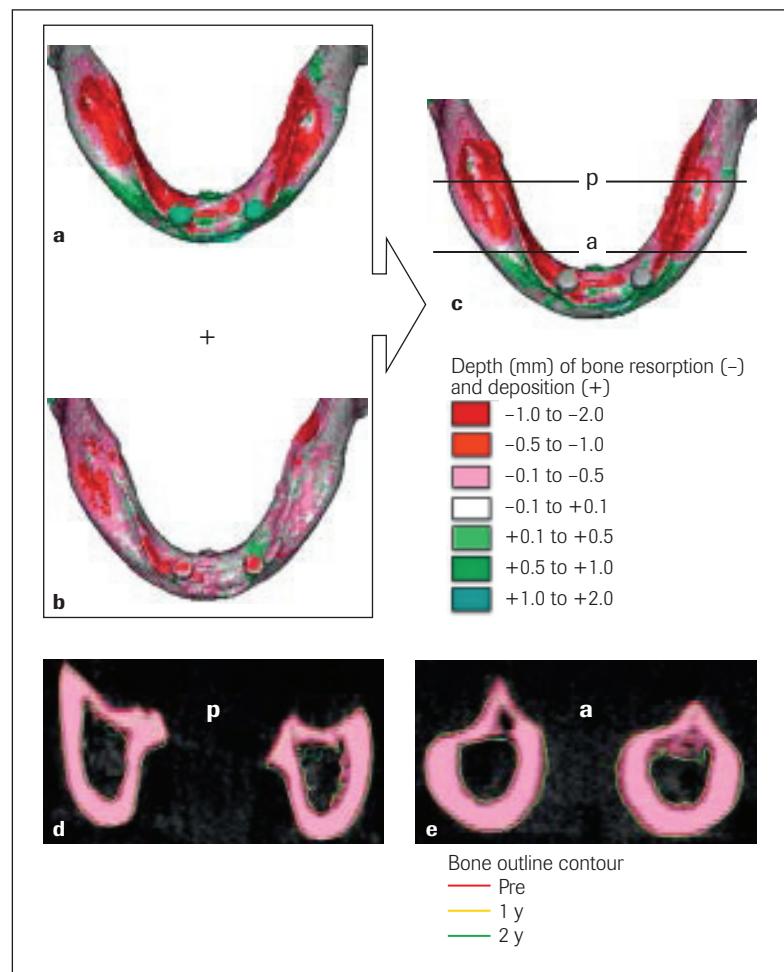
A total of 25 participants were treated with implant-retained overdentures. However, by the end of the 2-year follow-up, only 18 participants' data were complete for analysis. Of the 25, 2 did not follow up due to death and severe illness, 3 had to be excluded because of poor-quality radiographs, and 2 were excluded because they did not wear the overdentures regularly. Data for the four participants who received complete dentures were available after the first year only.

The values, means, and standard deviations for total RRR over a 2-year period and measurements of gonial angle, ramus length, ramus width, corpus height, and corpus length for the 18 overdenture

participants are shown in Table 1. The mean gonial angle was  $129.23 \pm 8.29$  degrees. There was no significant difference in gonial angle between men and women. The most acute angle was 113.70 degrees, while the most obtuse angle was 141.30 degrees. Of the participants, 9 had gonial angles below the average value and were assigned the lower gonial angle group, and the other 9 recorded above the average value and were assigned the higher gonial angle group. For all measurements of the mandibular morphology, the intraclass correlation coefficients of reliability were found to be greater than 0.91.

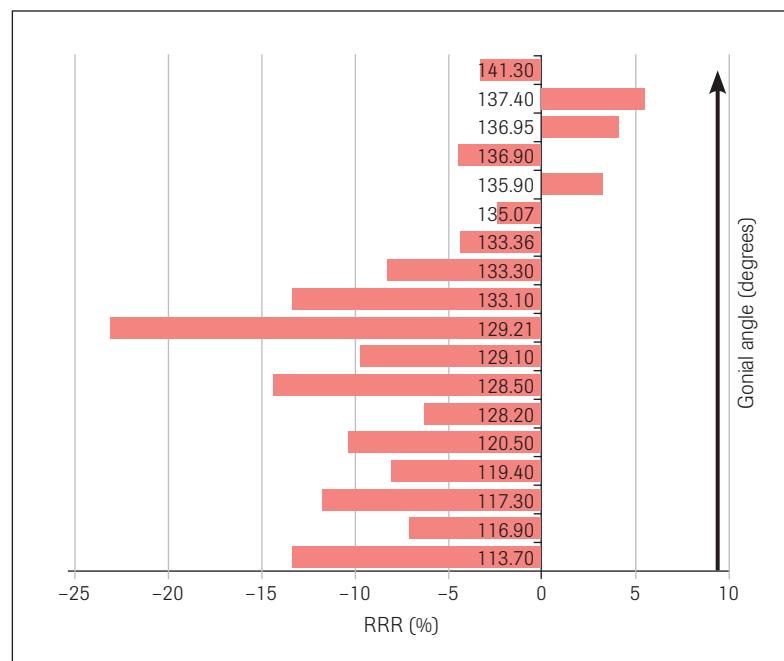
The extent of RRR is highly variable among participants. Most demonstrated some degree of bone loss, while a few others demonstrated bone gain. The mean total RRR as measured by changes in bone volume that occurred over a period of 2 years was  $-7.0\% \pm 7.16$ .

**Fig 2** Quantification of residual ridge resorption. Color maps of bone dimensional changes that took place **(a)** during the first year and **(b)** during the second year. **(c)** Color map of the combined total dimensional bone changes after 2 years. **(d)** Bone outline contours in the coronal section of the posterior (*p*) region. **(e)** Bone outline contours in the coronal section of the anterior (*a*) region. RRR could be observed to have occurred either by displacement of the entire thickness of the cortical layer apically or by thinning of the surface layer.

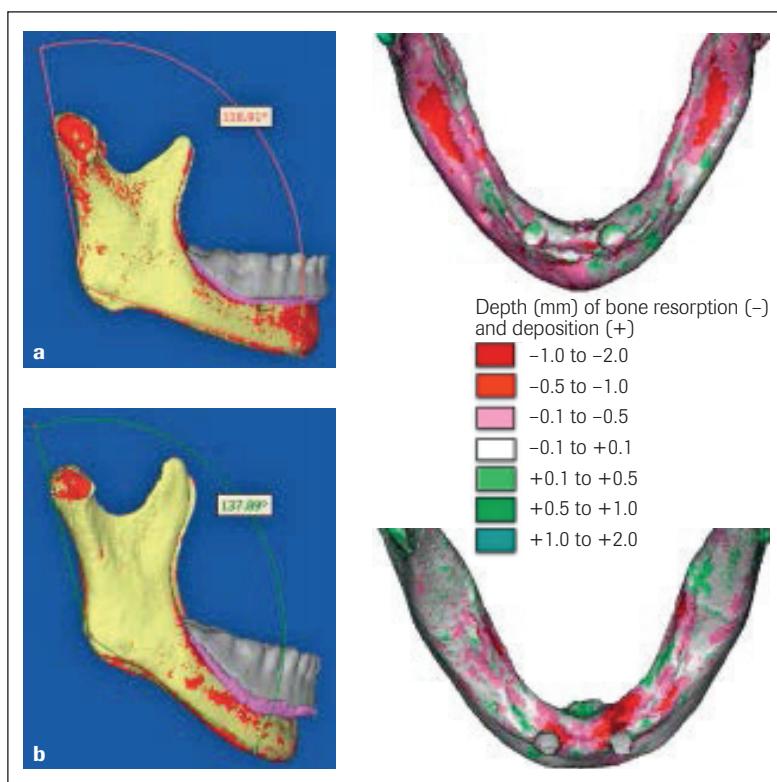


The most extensive RRR of  $-23\%$  was observed in the oldest female participant (79 years) in this study. However, there was no significant difference in mean RRR by sex ( $P = .344$ ) or by age of participants ( $P = .116$ ). The mean decrease in bone volume after the first year was  $3.8 \pm 4.5\%$ . During the second year, the rate reduced slightly, to  $3.2 \pm 4.1\%$  per year. Resorption occurs either by translation of the entire thickness of the cortical layer apically or by thinning of the outer cortical layer (Fig 2). The depth of bone resorption and deposition ranges from  $-2$  to  $+2$  mm.

Gonial angle, ramus length, ramus width, corpus length, and corpus height were tested as possible explanatory variables for RRR (Table 2). Pearson correlation coefficient showed that there was a significant association between RRR and gonial angle ( $r = .471; P = .048$ ). There was no association between RRR and ramus length ( $r = -.341; P = .166$ ), ramus width ( $r = -.183; P = .468$ ), corpus length ( $r = .057; P = .821$ ), or corpus height ( $r = .097; P = .702$ ). Participants with low gonial angle demonstrated significant RRR. Participants with high gonial angle demonstrated significantly less bone loss, and three of these recorded a net bone gain (Fig 3).



**Fig 3** Percentage of total RRR after 2 years in relation to gonial angle. As the size of the gonial angle increases, less RRR occurs. Positive modeling (bone apposition) was also demonstrated toward the higher end of the gonial angle spectrum.



**Fig 4** Comparison of the extent and location of RRR in participants with (a) low and (b) high (B) gonial. In the participant with a low gonial angle, RRR is more pronounced and occurred predominantly in the posterior region. RRR tended to occur less extensively and was located more anteriorly in the participant with a high gonial angle. Note that the occlusal plane of the low-angle participant (a) is horizontal, whereas that of the high-angle participant (b) is anteriorly inclined.

The location of predominant RRR was also influenced by the gonial angle. For participants with low gonial angle, resorption occurred predominantly on the occlusal surface of the denture-bearing area in the molar region. In participants with high gonial angle, resorption tended to occur more anteriorly and lingually (Fig 4).

The number of complete denture participants is too small for statistical analysis. However, the gonial angle distribution is comparable with that for the overdenture participants. The gonial angles of the four complete denture participants were 111.9, 124.4, 132.7, and 137.2 degrees, respectively. The RRR pattern also follows that of overdenture participants: less RRR was observed as gonial angle increased. However, the resorption rate for this group was about half that of the overdenture group, at  $-1.9\% \pm 0.4$  after the first year.

## Discussion

This prospective clinical study investigated the effects of mandibular morphology on RRR over 1- and 2-year periods. The limitations of the small study cohort of 18 participants remaining after the 2-year follow-up for the overdenture and 4 participants for the complete denture must be acknowledged, and the findings presented should be interpreted with caution. The comparison of the outcome of RRR between overdenture and complete denture would have been

more meaningful if the number of participants in the latter group could be increased to a similar number. However, for obvious ethical reasons, this was not possible. Consideration was given by the ethics committee for a single follow-up CBCT of the four complete denture participants because they had had a diagnostic CBCT taken.

The increased radiation associated with CBCT imaging is another concern. However, the effective radiation dose used in this study was only 101.5  $\mu$ Sv, which is equivalent to 3% or 12 days of background radiation. The annual effective dose limit for infrequent exposure has been recommended at 5,000  $\mu$ Sv.<sup>26</sup> Due to this low dosage of radiation, repeated imaging with CBCT at 6-month or yearly intervals has become common practice in studies comparing treatment effects on bone structure.<sup>27-29</sup>

It is imperative to determine whether a strong predictor exists within the mandibular morphologic features for RRR so that practitioners may use this knowledge to plan the most suitable treatment for a specific patient to minimize RRR. Based on this study, the gonial angle is a good predictor of RRR ( $r = .471$ ;  $P = .048$ ) and the effect was observed in both the overdenture and the complete denture participants. Participants with low gonial angles suffered more bone resorption than their high-angle counterparts. This finding is similar to that reported by Tallgren<sup>1</sup> and could be due to the elevator muscles' higher

mechanical advantage associated with the low gonial angle individuals, as described by Throckmorton et al,<sup>23</sup> who demonstrated that as the gonial angle increases from 90 to 150 degrees, the mechanical advantage decreases by 55% for the temporalis and masseter muscles. This means that for the same muscle force, individuals with a high gonial angle may generate less stress in the soft tissue mucosa overlying the denture-bearing areas, which may lead to less bone resorption.<sup>30,31</sup> In this study, three of seven patients with high gonial angles experienced a positive percent increase in RRR. This could be due to the low pressure exerted on the mucosa, which enhances blood flow rather than impedes it<sup>32</sup> and thereby may have contributed to bone deposition.<sup>33–37</sup>

Participants with high gonial angle also tend to have an occlusal plane that is inclined anteriorly, whereas for those with low angle the occlusal plane tends to be more horizontal (Fig 4). Ogawa et al<sup>37</sup> have shown that subjects with anteriorly inclined occlusal plane demonstrated a vertical closing path of the masticatory movement, whereas subjects with a more horizontal occlusal plane showed a flat closing path in the frontal plane. This could mean that more force will be transferred to the prosthesis in patients with low gonial angle as more lateral contacts and displacement of the prosthesis will occur when the closing path of the masticatory movement is flat.

The angulations of the masseter have been reported to be more anteriorly inclined relative to the occlusal plane in individuals with large gonial angles and more vertical in those with a small gonial angle,<sup>22</sup> and this could further explain the difference in magnitude and locations of major areas of RRR in these two groups. Where the masseter is more vertical, as with low angle, not only is the bite force higher but the direction of the force is more vertical, resulting in more bone loss in the immediate posterior region. In high-angle individuals the anterior inclination of the masseter resulted in a reduced mechanical advantage and produced a more anterior component of the force to cause RRR at the anterior and lingual part of the mandible. This phenomenon was observed in dentate individuals. The low-angle patient has very little mesial drift of the natural dentition, while the posterior teeth of the high-angle patient are more prone to mesial drifting.<sup>2</sup>

The other features of mandibular morphology do not seem to significantly influence the rate of RRR. This could be due to the lesser direct influence that these features have on the size/volume and angulation of the elevator muscles.

RRR seems to be more rapid in the first year than in the second year, as evidenced by the closer proximity of the 1- and 2-year bone outline contours compared with the pretreatment and 1-year bone contours

(Figs 2d and 2e). This phenomenon is similar to what has been reported by Carlsson and Persson<sup>38</sup> and Tallgren,<sup>39</sup> who attributed this phenomenon to the external molding force applied by the denture, or the denture-settling effect. Once the bone has remodeled following the shape of the denture-fitting surface, a process which takes about 6 months to a year, less resorption appears to occur over the next few years as the force may be less traumatic after it becomes better distributed over the adapted occlusal ridge.

Comparison of the RRR rate after the first year between the implant-retained overdenture and complete denture situations in this study seems to indicate that more bone resorption (twofold) occurs with the former group. This finding is similar to other studies comparing bone resorption between complete denture and implant-retained overdenture situations. Jacobs et al<sup>6</sup> and Finger and Guerra<sup>7</sup> found that there was more bone resorption in the implant-retained denture group and the resorption rate was two to three times that of a complete denture. This difference could be due to the two to three times stronger bite force found in implant-retained overdenture patients compared with the complete denture wearers.<sup>9</sup>

The process of RRR seems to occur in two different ways. In some areas, bone resorbs by apical shifting of the entire cortical layer, as can be seen in the left mandible in Fig 2d. In other areas, such as the right side of the mandible in Fig 2d, RRR occurs by thinning of the cortical layer to the extent of causing perforations on the cortical surface. Why this occurs will be investigated further and will be the subject of a separate paper in which the thickness of the overlying mucosa and associated stresses that result from masticatory pressure will be analyzed and related to RRR.

## Conclusions

Within the limitations of this study, it may be concluded that the gonial angle has a significant relationship with the magnitude and location of RRR. It may be the provision of implant-retained overdentures for patients with low gonial angle should be selectively recommended due to the associated high rate of bone resorption related to the larger mechanical advantage of the elevator muscles.

## Acknowledgments

This study was funded by Universiti Teknologi MARA and the Ministry of Higher Education, Malaysia (ERGS/1/2013/SKK11/Uitm/02/01), as well as by Australia Malaysia Institute (AMI). The authors are grateful to all subjects who participated in this study and to Dr Budi Aslinie Md Sabri for the statistical advice. The authors reported no conflicts of interest related to this study.

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# Fractographic Analysis of a Clinically Failed FPD After 10 Years in Service

Youssef S. Al Jabbari, BDS, MS, FACP, PhD<sup>1</sup>

This study retrieved and analyzed by scanning electron microscopy (SEM) and energy-dispersive x-ray spectroscopy (EDS) the failure of a single four-unit fixed partial denture (FPD). Low SEM magnifications revealed a smooth/featureless fracture surface, indicating brittle fracture. Higher magnifications revealed a small fatigue fracture region located on the inferior part of the connector. EDS analysis indicated that the FPD alloy was gold-based. Additionally, SEM showed segregation of small spherical particles at grain boundaries of the alloy, with high aluminum and oxygen content. The particles, most likely retained aluminum, possibly resulted from sandblasting procedures for a scrap metal alloy, which was then recast into a new FPD. It appears that the fracture was initiated in the oral cavity by fatigue crack formation, but the presence of  $\text{Al}_2\text{O}_3$  particles facilitated alloy embrittlement and brittle fracture. *Int J Prosthodont* 2016;29:581–583. doi: 10.11607/jp.4878

To date, no studies have reported failure analysis of metal-ceramic fixed partial dentures (FPDs), and most available ones focus instead on all-ceramic FPDs.<sup>1</sup> Metal-ceramic FPDs have long been considered the replacement of choice for missing teeth, and the longevity of FPDs fabricated from high-noble alloys was found to be 83% after 14 years.<sup>2</sup> Studies related to intraorally failed FPDs provide valuable information that may help optimize clinical performance and minimize manufacturing and handling errors. The aim of this study was to perform fractographic analysis on a retrieved clinically fractured dental FPD after 10 years of service, describing the fractographic pattern, identifying the failure origin, and speculating on reasons for failure.

## Materials and Methods

A 54-year-old man came to the emergency clinic complaining of a displaced full cast crown, which was a distal abutment for a four-unit FPD replacing a missing mandibular left second premolar and first molar

(Fig 1). The patient reported no problems related to his FPD except that, while eating breakfast, he heard a sudden clicking noise, after which the full cast crown was fully displaced due to a fracture occurring at the connector area after the FPD had been in service for 10 years. The retrieved crown was subjected to a thorough failure analysis by scanning electron microscopy (SEM) (JSM-6360 LV, JEOL). Energy-dispersive x-ray spectroscopy (EDS) (Thermo Scientific) was used to determine the qualitative and semiquantitative average alloy composition. A metallographic specimen was prepared from a small alloy piece cut from the connector opposite the fracture surface. After the specimen was finished and polished, the alloy was chemically etched with aqua regia solution (45% hydrochloric acid, 25% nitric acid, and 30% water) to reveal its microstructure.

## Results

At low SEM magnification, the fracture surface appeared relatively smooth and featureless, without any plastic deformation indicating brittle fracture occurrence (Fig 2a). Examination under higher SEM magnification revealed an intergranular brittle fracture characterized by a rock candy appearance covering the entire fracture surface (Fig 2b) and a small fatigue fracture region characterized by fatigue striations located on the inferior part of the connector area and covering only a small area (Fig 2c). At a very high SEM magnification, small spherical particle segregation was detected at grain boundaries of the alloy (Fig 2d). EDS analysis revealed that the FPD alloy consisted of 84 wt% gold (Au) and 6 wt% palladium (Fig 3a). Spot analysis revealed that segregated particles showed a

<sup>1</sup>Director, Dental Biomaterials Research and Development Chair, and Director, College of Dentistry Research Center, College of Dentistry, King Saud University, Riyadh, Saudi Arabia; Associate Professor, Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, Riyadh, Saudi Arabia.

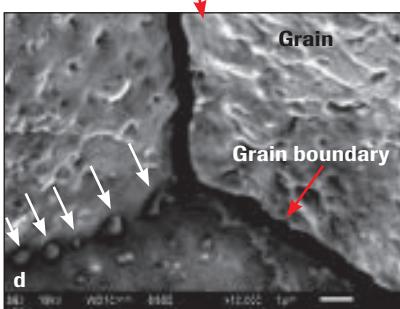
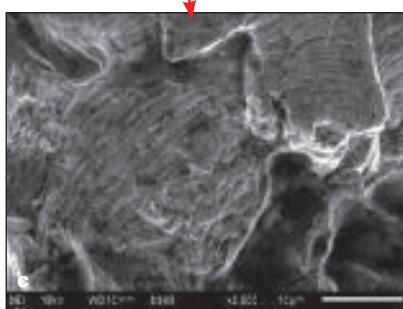
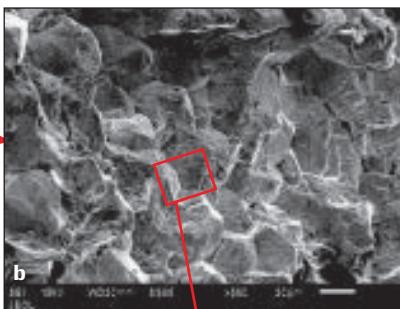
**Correspondence to:** Dr Youssef S. Al Jabbari, Department of Prosthetic Dental Sciences, College of Dentistry, King Saud University, PO Box 60169, Riyadh 11545, Saudi Arabia. Fax: +966 1 4698313.

Email: yaljabbari@ksu.edu.sa

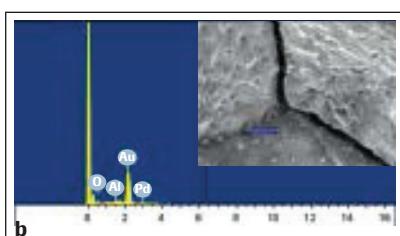
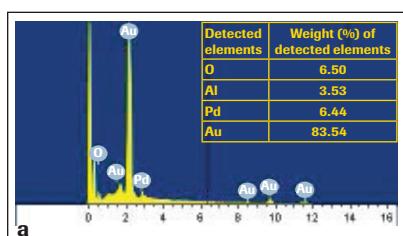
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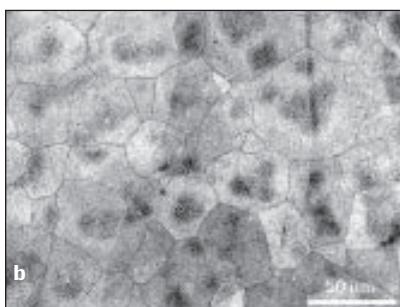
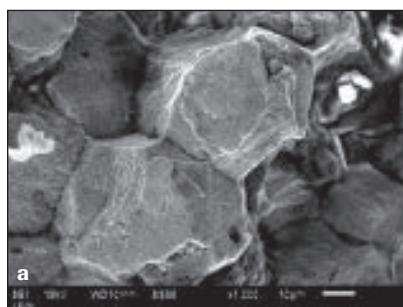
**Fig 1** **(a)** The displaced distal retainer on the mandibular left second molar. Note the fracture occurrence at the connector area (arrow). **(b)** Periapical radiograph showing the fractured FPD and the displaced retainer from the abutment tooth.



**Fig 2** Fractographic SEM images of the connector. **(a)** Smooth, featureless surface indicating brittle fracture at  $\times 20$ . **(b)** Intergranular brittle fracture characterized by rock candy appearance at  $\times 550$ . **(c)** Fatigue striation within a small zone located at the inferior part of the connector at  $\times 2,600$ . **(d)** Segregated alumina particles at the grain boundaries (white arrows) at  $\times 10,000$ .



**Fig 3** **(a)** EDS X-spectrum of area analysis and **(b)** EDS X-spectrum from spot analysis of a small particle at grain boundaries as indicated in the embedded SEM photomicrograph.



**Fig 4** **(a)** Fractographic SEM image showing rock candy appearance revealing the shape of an individual grain at  $\times 1,000$ . **(b)** Light micrograph after etching showing a homogenous microstructure with equiaxed grains (33- $\mu\text{m}$  grain size). Note that the revealed equiaxed grains in **(b)** resemble the grain shape in **(a)**.

high content of aluminum (Al) and oxygen (O) (Fig 3b). The revealed microstructures of the Au-based alloy

were homogenous equiaxed grains of approximately 33  $\mu\text{m}$  average grain size (Fig 4).

## Discussion

Since the patient came to the clinic holding the crown, failure was initially expected to result from cement dissolution under the crown of the distal abutment. Based on the study findings, the likely scenario causing connector fracture was cement dissolution under the most distal crown retainer leading to increased FPD bending under function, causing fatigue crack initiation at a very small area of the inferior part of the connector region. When suddenly subjected to a higher single functional load, the crack propagated, leading to brittle failure (intergranular fracture) that the patient heard when the crown came off the abutment tooth.

The unique and unexpected observation of this study is the occurrence of intergranular brittle fracture of a high-noble alloy under cyclic functional loading. Normally, the expected failure type in such alloys is ductile fracture, characterized by significant plastic deformation (such as striations and beach mark formation), with final ductile rupture (dimple formation) as previously documented.<sup>3</sup>

Intergranular fracture is a form of brittle fracture related to low-energy failure. It is sometimes caused by processing problems and is known as *rock candy* in cast alloys with coarse grain size<sup>4</sup> (Fig 2) resembling the individual grain size of cast alloys (Fig 4). Based on the present findings, brittle fracture occurrence indicates alloy embrittlement of FPD substrates. The observed segregated alumina particles ( $\text{Al}_2\text{O}_3$ ) at grain boundaries were possibly the main cause of alloy embrittlement. The particles were most likely retained alumina resulting from laboratory sandblasting of a scrap high-noble alloy before casting. When the alloy was melted and cast, the alumina particles were incorporated into molten alloy and segregated preferentially at grain boundaries during cast alloy solidification. Recasting scrap high-noble alloys (such as remaining casting sprues) is done mainly to reduce the expense of the new restoration. It is important to mention that recasting of dental alloys is not an acceptable and normal laboratory procedure because it may adversely affect the mechanical, physical, and biologic properties of the alloy. Recasting scrap dental alloys to reduce the cost should not be done at the expense of the optimum properties of the alloy.

Retention of alumina on alloy surfaces post-sandblasting has been documented, and the presence of retained particles has been suggested to adversely affect cast alloys.<sup>5</sup> Therefore, sandblasting conditions (eg, alumina particle sizes, propulsion pressure) must be monitored to avoid and/or minimize particle retention. Before the alloy is cast, thorough ultrasonic cleaning might be helpful in minimizing retained alumina particles.

## Conclusions

Recasting scrap alloys is an abuse of normal and acceptable laboratory protocols and must be avoided. If a scrap high-noble dental alloy is to be recast, the following should be kept in mind:

- Retained sandblasting alumina in high-noble dental alloy may alter cast alloy mechanical properties and in-service behavior and may cause alloy embrittlement.
- Attention to sandblasting conditions and ultrasonic cleaning of alloys after sandblasting and before casting may help minimize retained alumina particles.

## Acknowledgments

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# Immediate Loading of Anterior Single-Tooth Implants Placed in Healed Sites: Five-Year Results of a Randomized Clinical Trial

Laurens den Hartog, DDS, PhD<sup>1</sup>/Gerry M. Raghoebar, DDS, MD, PhD<sup>2</sup>/Kees Stellingsma, DDS, PhD<sup>1</sup>/Arjan Vissink, DDS, MD, PhD<sup>2</sup>/Henny J.A. Meijer, DDS, PhD<sup>2,3</sup>

**Purpose:** The aim of this study was to compare the 5-year outcome of immediate loading with that of conventional loading for anterior single-tooth implants placed in healed sites. It was hypothesized that immediate loading is not inferior to conventional loading. **Materials and Methods:** A total of 62 patients with a missing maxillary anterior tooth were included. At random, patients were treated with an implant that was restored either with a nonoccluding temporary crown within 24 hours after implant placement (immediate group) or according to a two-stage procedure after 3 months (conventional group). All implants were placed in healed sites. Follow-up visits were performed after definitive crown delivery and 1 and 5 years thereafter. Outcome measures were radiographic marginal bone level changes, implant survival, complications, soft tissue aspects (probing depth, plaque, bleeding, soft tissue level changes), esthetic outcome, and patient satisfaction. **Results:** Three patients in each study group were lost to follow-up. No significant differences were found in terms of marginal bone loss ( $1.16 \pm 0.93$  mm in the immediate group and  $1.20 \pm 1.10$  mm in the conventional group), survival (one implant lost in the immediate group), complications, soft tissue aspects, esthetic outcome, and patient satisfaction. **Conclusion:** For anterior single-tooth implants placed in healed sites, the outcome of immediate loading is not inferior to conventional loading. *Int J Prosthodont* 2016;29:584–597. doi: 10.11607/ijp.4993

**L**oss of anterior teeth affects not only oral functions but also esthetic appearance. The patient usually has a strong wish to restore function and esthetics quickly with a restoration that is durable and resembles the adjacent dentition. Dental implants meet these wishes, especially when a restoration is immediately placed after implant placement. This concept has been defined as immediate loading and implies that the implant is loaded within 48 hours by means of a restoration,<sup>1</sup> thus before the implant is integrated into the bone.

With immediate loading, overall treatment time is shortened, second-stage surgery is not needed, and immediate comfort is brought to the patient as there

is no need for a (removable) temporary prosthesis during healing. On the other hand, immediate loading might induce micromotion and instability of the implant, caused by forces of the opposing dentition, contact with food, and lip and tongue pressure, jeopardizing successful osseointegration.<sup>2</sup>

One may argue that, with respect to immediate loading, complications will occur in the short term in particular. It is not known, however, how the peri-implant tissue of immediately loaded implants behaves over the longer term as the marginal bone is loaded immediately after implant placement and bone is exposed to the oral cavity via the (provisional) restoration. Those conditions create a risk of poorer osseointegration and consequently progressive or sudden marginal bone loss over the longer term. Therefore, it is of paramount importance to determine, by means of well-designed randomized clinical trials (RCTs), whether immediate loading is safe, including for longer follow-up periods.

Published RCTs on immediate loading of single implants in the esthetic zone are scarce, and the follow-up periods of these trials are too short to draw firm conclusions for longer follow-up periods.<sup>3,4</sup> Furthermore, outcome measures reflecting peri-implant tissue health, esthetics, and patient satisfaction are often underexposed.<sup>3,4</sup> Therefore, the aim of

<sup>1</sup>Assistant Professor and Researcher, University of Groningen, University Medical Center Groningen, Department of Oral and Maxillofacial Surgery, Groningen, The Netherlands.

<sup>2</sup>Professor, University of Groningen, University Medical Center Groningen, Department of Oral and Maxillofacial Surgery, Groningen, The Netherlands.

<sup>3</sup>Professor, University of Groningen, University Medical Center Groningen, Dental School, Department of Fixed and Removable Prosthodontics, Groningen, The Netherlands.

**Correspondence to:** Dr L. den Hartog, Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, Hanzeplein 1, PO Box 30.001, 9700 RB Groningen, The Netherlands.  
Email: l.den.hartog@umcg.nl

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this 5-year follow-up study was to compare the outcome of immediate loading with that of conventional loading of implants for replacing a missing anterior tooth. It was hypothesized that the outcome of immediate loading is not inferior to conventional loading.

## Materials and Methods

This article presents the 5-year follow-up data after definitive crown placement of single-tooth implants in the anterior region. In an earlier published article, 1-year follow-up data after definitive crown placement was presented.<sup>5</sup> The earlier publication provides a more detailed description of the materials and methods used.

### Study Design

This randomized, noninferiority clinical trial was conducted at the department of Oral and Maxillofacial Surgery of the University Medical Center Groningen, University of Groningen, Groningen, The Netherlands. A locked computer software program was used to randomly assign patients with a 1:1 allocation ratio to one of two study groups to receive a NobelReplace Tapered Groovy implant (Nobel Biocare) that was restored either within 24 hours after implant placement (immediate group) or according to a routine two-stage procedure after 3 months of healing (conventional group). Randomization by minimization was performed to minimize the imbalance between study groups. The following factors were taken into account: age ( $\leq 30$  years,  $> 30 \leq 60$ , or  $> 60$  years), location of the implant (central or lateral incisor/canine or first premolar) and indication for a preimplant bone augmentation procedure. The allocation result was kept in a locked computer file that was not accessible to the examiner or the practitioners. The surgeon that placed the implants was informed about the allocation on the day of surgery, before the implant was placed.

### Patients

Patients referred to the department for anterior single-implant treatment were considered for inclusion if they met the following criteria:

- $\geq 18$  years of age
- One missing incisor, canine, or first premolar in the maxilla with adjacent natural teeth
- Adequate oral hygiene (ie, modified plaque index score and modified sulcus bleeding index score  $\leq 1$ )<sup>6</sup>
- Mesial-distal width of interdental space  $\geq 6$  mm
- Vertical occlusal dimensions permitting creation of a nonoccluding temporary crown

Exclusion criteria were as follows:

- ASA score  $\geq III$ <sup>7</sup>
- Presence of active clinical periodontal disease as expressed by probing pocket depths  $\geq 4$  mm and bleeding on probing
- Presence of periapical lesions or any other abnormalities in the maxillary anterior region as determined on a radiograph
- Smoking
- A history of radiotherapy to the head and neck region

### Interventions

All implants were placed in healed sites (ie, the anterior tooth was removed at least 3 months prior to implant placement). When bone volume was insufficient for implant placement, a bone augmentation procedure was carried out with autogenous and anorganic bovine bone covered with a collagen membrane. In these cases, implants were inserted 3 months after the augmentation procedure.

Implants were placed with a torque controller adjusted to an insertion torque of 45 Ncm. A manual torque controller was used to realize proper implant depth if this torque was reached before the implant had reached its planned position. If necessary, implant dehiscences or fenestrations were covered with autogenous bone chips and anorganic bovine bone overlaid with a collagen membrane.

In the immediate group, an implant-level impression was made. Within 24 hours, a screw-retained temporary crown was placed in the immediate group. This crown was free from centric contacts with the antagonist teeth. Patients were instructed to follow a soft diet and to avoid exerting force on the temporary restoration.

Patients in the conventional group wore a removable partial denture that did not interfere with the wound. These implants were uncovered after 3 months and restored with a temporary crown according to the same procedure as in the immediate group.

After a temporary phase of 3 months for the conventional group and 6 months for the immediate group (6 months post-implant placement for both study groups), a definitive all-ceramic crown was made consisting of an individually fabricated zirconia abutment. Depending on the location of the screw access hole, crowns were screw-retained or cement-retained. Surgical procedures were performed by an experienced oral and maxillofacial surgeon (G.M.R.). The prosthetic procedure was done by two experienced prosthodontists (H.J.A.M. and K.S.), and all crowns were fabricated by a single technician.

**Table 1** Baseline Characteristics of Included Patients

Variable	Immediate group (n = 31)	Conventional group (n = 31)
Mean age $\pm$ SD (range) (y)	38.4 $\pm$ 14.0 (18–66)	40.1 $\pm$ 14.4 (18–67)
Sex		
Men	9	17
Women	22	14
Tooth gap position		
Central incisor	14	18
Lateral incisor	10	8
Canine	4	3
First premolar	3	2
Preimplant bone augmentation performed <sup>a</sup>	9	11
Implant diameter		
3.5 mm	10	10
4.3 mm	21	21
Implant length		
13 mm	4	2
16 mm	27	29
Final restoration		
Screw-retained	12	12
Cement-retained	18	19

<sup>a</sup>Implants were installed after 3 months.

## Outcome Measures

The primary outcome measure of this study was radiographic marginal bone level change proximal to the implant measured from implant placement to 5 years after definitive crown placement. Secondary outcome measures were implant survival, biologic and technical complications, change in peri-implant mucosal level, esthetic outcome, papilla volume, amount of plaque, bleeding on probing, probing pocket depth, and patient satisfaction. All measurements were done by the same examiner (L.d.H.). The operationalization of variables is described below.

## Radiographic and Photographic Assessments

After implant placement (baseline), after final crown placement ( $T_0$ ), and 1 ( $T_1$ ) and 5 years ( $T_5$ ) after final crown placement, standardized radiographs were taken. Standardized photographs were taken at  $T_0$ ,  $T_1$ , and  $T_5$ . The radiographic and photographic procedures have been described in detail by Meijndert et al.<sup>8</sup> The examiner was blinded for the photographs and the radiographs taken at  $T_0$ ,  $T_1$ , and  $T_5$ . The radiographic examination could not be blinded for the radiographs taken immediately after implant placement (baseline), since the study group could be deduced from these radiographs. Full-screen analysis of the radiographs was performed using specifically designed

software. Full-screen analysis of the photographs was performed using Adobe Photoshop (Adobe Photoshop CS3 Extended, Adobe Systems). Midfacial mucosal and papilla levels of the implant were measured at  $T_0$ ,  $T_1$ , and  $T_5$ . The intra- and interobserver agreements of the radiographic and photographic examinations were tested earlier and reported as acceptable.<sup>5,8</sup>

## Clinical Assessments

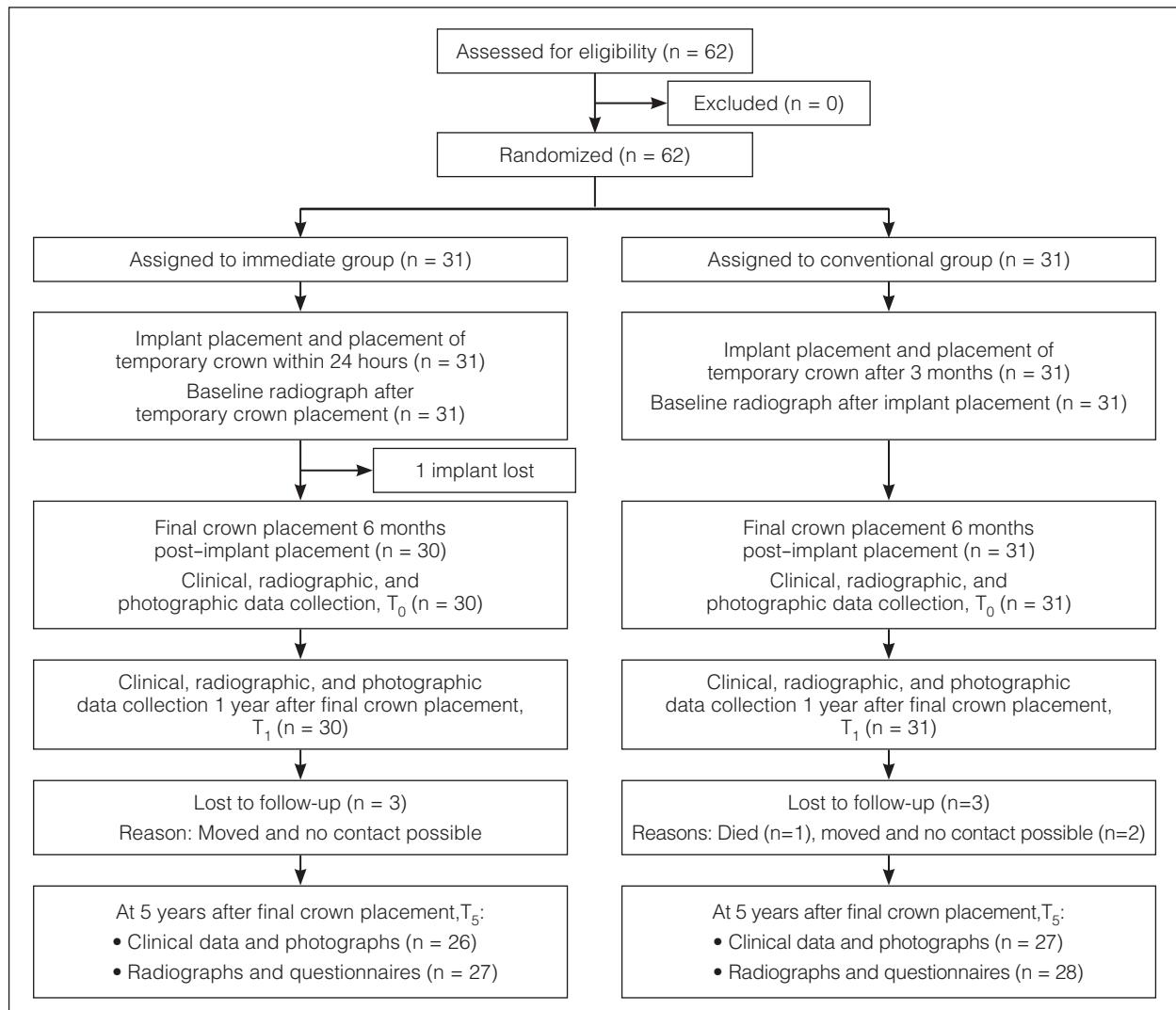
Before implant placement and at  $T_0$ ,  $T_1$ , and  $T_5$ , patients were seen for clinical data collection. The examiner was blinded for the group allocation. The variables were plaque, using the modified plaque index;<sup>6</sup> bleeding, using the modified sulcus bleeding index;<sup>6</sup> probing pocket depth, measured to the nearest 1 mm using a manual periodontal probe; volume of the interproximal papilla, using the papilla index<sup>9</sup>; and width of attached mucosa, using the attached mucosa index.<sup>10</sup> During follow-up, the following complications were registered: implant loss; fracture or deformation of implant, retention screw, or abutment; fracture of the coping (for cemented crowns); chipping of the veneering material; screw or abutment loosening; loss of retention of the cemented crown; presence of fistula; and peri-implantitis. Peri-implantitis was defined according to the consensus reached at the Seventh European Workshop on Periodontology,<sup>11</sup> being bleeding on probing and/or suppuration in combination with radiographic bone loss  $\geq 2$  mm (after definitive crown placement,  $T_0$ ).

## Esthetic Assessments

The esthetics of the peri-implant mucosa and implant crown were determined on photographs taken at  $T_1$  and  $T_5$  using the Pink Esthetic Score/White Esthetic Score (PES/WES).<sup>12</sup> The examiner was blinded for the group allocation. The inter- and intraobserver reliability was assessed earlier and reported as acceptable.<sup>5</sup>

## Patient Satisfaction

Patient satisfaction was assessed using a self-administered questionnaire to be completed at  $T_0$ ,  $T_1$ , and  $T_5$ . The questionnaire comprised questions or statements regarding esthetics and function and could be answered on a 5-point rating scale ranging from very dissatisfied (1) to very satisfied (5). Scores of 4 or 5 were considered satisfied, and responses were dichotomized into satisfied versus not satisfied. Patients were also asked to mark their overall satisfaction on a 100-mm visual analog scale (VAS) ranging from very dissatisfied (0) to very satisfied (100).



**Fig 1** Randomization, treatment procedure, and follow-up of study participants.

## Data Analysis

Immediate loading was considered inferior to conventional loading when showing 0.5 mm or more mean marginal bone loss during follow-up. The sample size calculation was reported earlier.<sup>5</sup> A minimum of 26 patients per group was required (power of 90%, one-sided significance level of 0.05). To compensate for withdrawal, the number of patients per group was set at 31.

For between-group comparisons of numeric and normally distributed variables (assessed using Kolmogorov-Smirnov test), *t* tests were used. Numeric variables that were not normally distributed were statistically explored with Mann-Whitney tests. Categorical variables were statistically explored using chi-square tests.

A significance level of .05 was chosen. Data were analyzed using SPSS version 22 (IBM).

## Results

Characteristics of included patients and details about the surgical and prosthetic procedures are shown in Table 1. All antagonist teeth were natural. Figure 1 is a flow chart of the randomization, treatment procedure, and follow-up period. All implants could be placed with a minimum insertion torque of 45 Ncm. For one patient in the conventional group and one in the immediate group, radiographs at T<sub>5</sub> were retrieved via their own dentists (patients had moved and were not able to return for oral examination).

### Marginal Bone Level Change

The mean marginal bone loss (mesial and distal implant sides combined) from implant placement (baseline) to 5 years after final crown placement (T<sub>5</sub>) was  $1.16 \pm 0.93$  mm in the immediate group (95%

**Table 2** Marginal Bone Level Changes from Implant Placement to 5 Years After Final Crown Placement

	Baseline-T <sub>0</sub>		T <sub>0</sub> -T <sub>1</sub>		T <sub>1</sub> -T <sub>5</sub>		Baseline-T <sub>5</sub>	
	Immediate (n = 30)	Conventional (n = 31)	Immediate (n = 30)	Conventional (n = 31)	Immediate (n = 27)	Conventional (n = 28)	Immediate (n = 26)	Conventional (n = 27)
Marginal bone level changes (mm)								
Mesial	-0.73 ± 0.54	-0.79 ± 0.62	-0.13 ± 0.55	-0.13 ± 0.40	-0.20 ± 0.63	-0.38 ± 0.97	-1.09 ± 0.92	-1.21 ± 1.11
Distal	-0.75 ± 0.68	-0.81 ± 0.76	-0.19 ± 0.35	-0.09 ± 0.41	-0.13 ± 0.44	-0.37 ± 0.79	-1.16 ± 0.93	-1.19 ± 1.14
Implant bone loss (%) <sup>a</sup>								
< 1 mm	71.6	62.9	96.7	100	94.4	82.1	56.5	55.4
1–2 mm	25	33.9	1.7	0	3.7	8.9	29.6	28.6
> 2 mm	3.3	3.2	1.7	0	1.9	8.9	13.9	16.1

<sup>a</sup> Mesial and distal sides combined.T<sub>0</sub> = immediately after final crown placement; T<sub>1</sub> = 1 year after final crown placement; T<sub>5</sub> = 5 years after final crown placement.**Table 3** Marginal Soft Tissue Level Changes from Final Crown Placement (T<sub>0</sub>) to 1 (T<sub>1</sub>) and 5 Years (T<sub>5</sub>) After

	T <sub>0</sub> -T <sub>1</sub>		T <sub>1</sub> -T <sub>5</sub>	
	Immediate (n = 30)	Conventional (n = 31)	Immediate (n = 26)	Conventional (n = 27)
Marginal soft tissue level changes (mm)				
Mesial	0.41 ± 0.49	0.19 ± 0.29	-0.09 ± 0.40	0.15 ± 0.60
Distal	0.27 ± 0.49	0.35 ± 0.52	0.29 ± 0.49	0.13 ± 0.63
Midfacial	0.06 ± 0.42	-0.09 ± 0.34	-0.02 ± 0.42	0.07 ± 0.49

T<sub>0</sub> = immediately after final crown placement; T<sub>1</sub> = 1 year after final crown placement; T<sub>5</sub> = 5 years after final crown placement.

confidence interval [CI]: 0.91–1.42) and 1.20 ± 1.10 mm in the conventional group (95% CI: 0.90–1.49) ( $P > .05$ ) (Table 2).

### Clinical Outcome

One implant in the immediate group was lost 3 weeks after placement due to high mobility. Survival rates at T<sub>5</sub> were 96.3% in the immediate group (1 implant lost out of 27 implants available for follow-up) and 100% in the conventional group (no implants lost out of 28 implants available for follow-up). Two patients in the immediate group and four in the conventional group developed peri-implantitis. Upon inquiry, it appeared that five of these six patients were smokers at the time of diagnosis, although they had reported no smoking habits at the time of inclusion.

Fracture of the veneering material (chipping) occurred in two patients in the conventional group and one in the immediate group. One patient in the immediate group received a new crown because esthetics were no longer acceptable after chipping. As a consequence, final crown survival rates were 96.3% in the immediate group and 100% in the conventional group. Mobility of the temporary crown occurred in one patient in the conventional group and in seven patients in the immediate group. Fracture of the temporary crown happened once in the conventional group.

No significant differences in soft tissue level changes around the implants were observed (Table 3).

The clinical assessments yielded no significant differences between the groups for probing pocket depth, bleeding index,

or papilla index (Table 4). At T<sub>5</sub>, a plaque score of 0 was given to all implants. The width of the keratinized epithelium around two implants in the conventional group was < 2 mm, whereas the width around all other implants was > 2 mm.

### Esthetic Outcome

The esthetics of the peri-implant mucosa were judged with a mean PES of 7.1 ± 1.5 (range: 3–10) for the immediate group and 6.5 ± 1.6 (range: 4–9) for the conventional group at T<sub>1</sub> ( $P > .05$ ). At T<sub>5</sub>, mean PES was 7.2 ± 1.5 (range: 3–10) for the immediate group and 6.8 ± 1.3 (range: 5–9) for the conventional group ( $P > .05$ ).

The esthetics of the implant crown were judged with a mean WES of 7.8 ± 1.5 (range: 4–10) for the immediate group and 7.6 ± 1.6 (range: 4–10) for the conventional group at T<sub>1</sub> ( $P > .05$ ). At T<sub>5</sub>, mean WES for the immediate group was 7.9 ± 1.2 (range: 5–9) and for the conventional group, 7.7 ± 1.2 (range: 5–10) ( $P > .05$ ).

### Patient Satisfaction

Patient satisfaction was high at all follow-up visits with no significant differences between study groups (Table 5).

### Discussion

This randomized clinical trial showed that the outcome of immediately loaded implants in the anterior zone is not less favorable than that seen with conventional loading. At 5 years after definitive crown placement (ie, 5.5 years after implant placement), no

**Table 4** Probing Pocket Depth, Bleeding Index Scores, and Papilla Index Scores

	T <sub>0</sub>		T <sub>1</sub>		T <sub>5</sub>	
	Immediate (n = 30)	Conventional (n = 31)	Immediate (n = 30)	Conventional (n = 31)	Immediate (n = 26)	Conventional (n = 27)
Probing pocket depth (mm)						
Mesial of implant	3.07 ± 0.91	3.03 ± 0.89	3.28 ± 1.03	3.19 ± 0.91	2.76 ± 0.78	3.31 ± 1.23
Distal of implant	3.37 ± 0.93	3.50 ± 0.82	3.62 ± 1.12	3.81 ± 1.28	3.04 ± 0.92	3.19 ± 1.20
Midfacial of implant	2.78 ± 0.58	3.07 ± 0.74	3.14 ± 0.92	3.32 ± 0.79	2.92 ± 1.41	3.15 ± 1.22
Bleeding index score (%)						
0: No bleeding	40.0	37.9	30.0	19.3	42.3	40.7
1: Isolated bleeding spots	43.3	34.5	50.0	48.4	46.2	40.7
2: Confluent line of blood	16.7	27.6	13.3	29.0	11.5	18.5
3: Profuse bleeding	0	0	6.7	3.2	0	0
Papilla index score (%) <sup>a</sup>						
0: No papilla	1.7	3.2	0	1.6	0	0
1: Less than half of the papilla	28.3	27.5	21.7	19.4	15.4	22.2
2: At least half of the papilla	51.7	46.8	35	45.2	48	51.9
3: Complete papilla	18.3	22.6	43.3	33.9	36.5	25.9

<sup>a</sup>Mesial and distal sides combined.T<sub>0</sub> = immediately after final crown placement; T<sub>1</sub> = 1 year after final crown placement; T<sub>5</sub> = 5 years after final crown placement.**Table 5** Patient Satisfaction (%) Regarding Function, Esthetics, and General Satisfaction

	T <sub>0</sub>		T <sub>1</sub>		T <sub>5</sub>	
	Immediate (n = 30)	Conventional (n = 31)	Immediate (n = 30)	Conventional (n = 31)	Immediate (n = 27)	Conventional (n = 28)
Function						
Eating	96.7	93.5	100	96.8	100	96.4
Speaking	96.7	93.5	100	100	100	100
Esthetics						
Color of the crown	100	100	93.3	96.8	92.6	96.4
Form of the crown	93.3	96.7	100	100	96.3	89.3
Color of the mucosa around the crown	96.7	90.3	96.6	87.0	96.3	92.9
Form of the mucosa around the crown	86.6	80.6	86.6	87.0	88.9	82.1
VAS score, (mean ± SD)	91.5 ± 8.4	89.5 ± 9.5	92.7 ± 9.0	89.0 ± 9.8	93.5 ± 7.1	91.3 ± 9.4

T<sub>0</sub> = immediately after final crown placement; T<sub>1</sub> = 1 year after final crown placement; T<sub>5</sub> = 5 years after final crown placement.

Percent satisfied patients on 5-point scale (4 or 5 equals satisfied or in agreement).

significant differences were found regarding implant survival, complications, soft tissue aspects, esthetic outcome, or patient satisfaction.

RCTs on immediate loading of anterior single implants are scarce, and the follow-up periods of these trials are short.<sup>3</sup> In a recent systematic review by Benic et al<sup>4</sup> in which immediately loaded implants were compared with conventionally loaded implants applied in all areas of indication, only 4 of the 29 included RCTs had a follow-up of 5 years or longer. Moreover, none of these 4 studies focused on single implants in the anterior zone. One RCT that did focus on this topic had a follow-up of 3 years.<sup>13</sup> In this study, narrow-diameter implants replacing lateral incisors were immediately loaded, resulting in no significant differences

compared with conventionally loaded implants that served as control. Not a RCT but more in line with the present study is the multicenter study by Cooper et al.<sup>14</sup> After 6 years, 49 implants installed in healed sites and subjected to immediate loading were available for evaluation. During follow-up, one implant was lost and crestal bone levels were in accordance with what has been reported for conventionally loaded implants.

One may argue that immediate loading is favorable for the esthetics of the peri-implant mucosa, since healing occurs against the natural form of the provisional crown and second-stage surgery is not taking place. In the present study, no differences in esthetic outcome between immediately and conventionally loaded implants were found when using the PES/

WES and papilla index as scoring systems. Indeed, the presumed positive effect of immediate loading on the esthetic outcome might be of a magnitude too small to be observed with these scoring systems. Another reason for not finding a difference could be that all implants were placed in healed sites. As described by Araújo and Lindhe,<sup>15</sup> tooth extraction and subsequent healing results in substantial resorption of the alveolus, significantly affecting the soft tissue anatomy. Probably, for implants placed in healed sites, the positive effect of immediate loading on the peri-implant mucosa subsides. The level and appearance of the mucosa before implant placement might be more relevant for the final aesthetics than the moment of provisional crown placement.

For implants placed immediately after tooth extraction, evidence is inconclusive regarding whether immediate loading would lead to more favorable soft-tissue levels compared with conventional loading. De Rouck et al<sup>16</sup> found that after 1 year of follow-up, midfacial recession was systematically higher following immediate placement and delayed loading, which resulted in 0.75 mm of additional soft tissue loss midfacially compared with immediate loading. These results, however, could not be confirmed in a recent RCT.<sup>17</sup>

During follow-up, 6 out of 53 patients (11.3%) were diagnosed with peri-implantitis. Although this percentage is in line with what has been reported in the literature,<sup>18</sup> the incidence of peri-implantitis was unexpectedly high given the strict inclusion and exclusion criteria and characteristics of included patients. At the time of inclusion, patients were to have adequate oral hygiene and no pockets  $\geq 4$  mm with bleeding. Smoking was an exclusion criterion, being a well-known risk factor for peri-implantitis.<sup>19</sup> Unfortunately, smoking was not successfully banished from this study and could have played an important role in the genesis of peri-implantitis, as five out of six patients who developed peri-implantitis reported that they smoked at the time of diagnosis although they reported not smoking at the time of inclusion. With respect to the characteristics of included patients, in the authors' opinion only a few patients had a history of periodontitis, another established risk factor for peri-implantitis.<sup>19</sup> In two cases, the tooth that was replaced with an implant had been lost due to periodontitis.

Technical complications related to the definitive crown were not common. Chipping was reported in three cases, corresponding with 5.7% of the population. This percentage is in agreement with the cumulative incidence of 3.5% after 5 years as calculated by Jung et al through meta-analysis.<sup>20</sup> Screw-loosening, the most frequently reported complication in this meta-analysis at 8.8% after 5 years, did not occur in the present study. Loosening of the temporary crown,

however, was not uncommon and occurred predominantly in the immediate group. It is possible that entrapment of bone or soft tissue at the implant-abutment interface on crown placement was causing this loosening. Since marginal bone resorption had not yet occurred around the implants that were immediately loaded, bone could have hampered temporary crown installation. As reported in an vitro study, tissue entrapment at the implant-abutment interface results in lower reverse torque values.<sup>21</sup>

A recent systematic review<sup>22</sup> compared immediate occlusal loading with immediate nonocclusal loading and suggested that immediate occlusal loading does not seem to have a negative effect on implant survival or marginal bone loss. This review also included studies in which implants were splinted and did not discriminate between anterior and posterior sites. The quality of included studies was also rather low: only 4 out of 11 had a low risk of bias. The present authors therefore believe that immediate occlusal loading in the esthetic zone is not evidence based and that it is better to make a nonoccluding provisional crown, as has been done in this study. It should be noted, however, that it can be rather difficult to keep a provisional crown out of occlusion, especially during eccentric jaw positions. It is therefore important to carefully instruct the patient to follow a soft diet and to avoid exerting force on the provisional.

To the best of the present authors' knowledge and as discussed earlier, there is no evidence that the use of a provisional crown leads to more favorable aesthetics for cases in which the implant is placed in a healed extraction site. However, marginal soft tissue levels are not stable. In this study, soft tissue gain was noted even long after final crown placement, especially at the proximal sites, and the rather high standard deviations are a sign of individual differences. Accordingly, it seems prudent to introduce a provisional phase to create a proper emergence profile and to monitor soft tissue maturation.

## Conclusions

This study shows that for anterior single implants placed in healed sites, the treatment outcome for immediate loading is not less favorable than that for conventional loading. Since immediate loading offers comfort for the patient, no need for second-stage surgery, and a shorter treatment period, this strategy should be considered as an alternative to conventional loading. However, it is presumed that immediate loading will be performed according to a strict protocol, paying attention to adequate primary implant stability, a nonoccluding provisional, and careful patient instruction.

## Acknowledgments

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### Literature Abstract

#### **The Impact of Diabetes on Dental Implant Failure: A Systematic Review and Meta-analysis**

The aim of this article was to investigate whether there is a difference in implant failure rate or marginal bone loss between subjects with type 1 or 2 diabetes and nondiabetic subjects. The authors reviewed 14 studies published between 2000 and 2015 (of those, only one article reported a subject with type 1 diabetes). All diabetes was under control at the time of surgery but was not monitored throughout the observation period. Absolute implant loss was considered as implant failure in this systematic review. The monitoring period in the studies ranged from 3 to 204 months (average: 45.1 months). There were no statistically significant differences between type 1 or 2 diabetes subjects and nondiabetic subjects for implant failure, nor were there differences between type 1 and type 2 diabetes. A statistically significant difference was found in favor of the nondiabetic group with regard to marginal bone loss. The authors mentioned that implant placement in bone regeneration areas (2 studies) and smoking habit (not reported in 5 studies) could have been confounding factors. In conclusion, the results of this systematic review suggested that the rate of implant failure is not higher for diabetic subjects than for nondiabetic subjects or between type 1 or type 2 diabetes. There was, however, a statistically significant difference favoring nondiabetic subjects in marginal bone loss.

**Moraschini V, Barboza ES, Peixoto GA.** *Int J Oral Maxillofac Surg* 2016;45:1237–1245. **References:** 41. **Reprint:** Vittorio Moraschini Filho, Department of Periodontology School of Dentistry, Fluminense Federal University, Rua Mario dos Santos Braga 30, Centro Niterói, Rio de Janeiro, CEP 24020-140, Brazil. Email: vittoriomf@terra.com.br —Huong Nguyen, USA

# The Role of Digitization in the Rapid Reproduction of an Obturator in a Frail Elderly Patient

Mahmoud E. Elbashti, BDS, MSc, PhD<sup>1</sup>/Yuka I. Sumita, DDS, PhD<sup>2</sup>/Mariko Hattori, DDS, PhD<sup>3</sup>/Amel M. Aswehlee, BDS, MSc<sup>4</sup>/Hisashi Taniguchi, DDS, PhD<sup>5</sup>

This case report describes the reproduction of the current obturator of a frail elderly patient using the digitization concept. A computed tomography scanner was used to scan the obturator. The virtual model was created using three-dimensional modeling software. The model was printed using a plastic with a low melting point with a fused deposition modeling technique in a three-dimensional printer and then conventionally processed. The definitive obturator was inserted and evaluated for fit, function, and esthetics and was successfully delivered at the second visit. The patient was satisfied with the oral function and esthetics of the reproduced obturator. This case report confirms the effectiveness of digitization in the reproduction of an obturator that enabled satisfactory oral function and esthetics. *Int J Prosthodont* 2016;29:592–594. doi: 10.11607/ijp.4932

Prosthetic rehabilitation for maxillectomy patients involves being fitted with an obturator, which is essential for oral functions such as speech, swallowing, and mastication, as well as for esthetics.<sup>1</sup> Old obturators have a negative effect on the oral function, esthetics, and psychosocial activities of frail elderly maxillectomy patients. Conventional obturator fabrication is complex and requires multiple scheduled appointments. An alternate process is needed for rapid fabrication in frail elderly cases, especially for patients who have difficulty regularly attending the clinic for treatment procedures. Digital technology is creating exciting opportunities for improving the delivery of maxillofacial prostheses.<sup>2</sup> Digitization of the obturator can play an essential role in reproducing

patient-specific obturators in a shorter time. This case report describes the reproduction of the patient's current obturator using the digitization concept.

## Case Report

An 89-year-old edentulous female maxillectomy patient had been visiting the maxillofacial prosthetics clinic for regular checkups (Fig 1). She had been wearing her obturator for more than 5 years. Consequently, the existing obturator (Fig 2) became unhygienic and needed to be replaced with a new obturator. As the patient had difficulty regularly attending the clinic for treatment procedures, an alternative rapid reproduction of the obturator with a less complicated treatment procedure was planned. The patient's current obturator was digitized using a cone-beam computed tomography (CBCT) scanner (3DX multi-image micro CT FPD, Morita), and the scanned obturator was saved in the Digital Imaging and Communication in Medicine (DICOM) file format. DICOM data were imported into Mimics 11.11 (Materialise) three-dimensional (3D) modeling software to produce a virtual 3D model, and saved as a binary Standard Tessellation Language (STL) file (Fig 3). The final STL file was evaluated for 3D printing suitability using 3D-printing software (Netfabb Studio Basic, Netfabb).

3D printing, which involves an automatic production technique guided by a digital 3D model, is a suitable technology for manufacturing complex geometric shapes. Obturators have a complex geometry that necessitates a layer-by-layer printing technique; therefore, fused deposition modeling technique was selected for 3D printing. A digitized 3D obturator model was manufactured using low-melting polylactic acid (Portabee 1.75-mm PLA 3D filament) in a 3D

<sup>1</sup>Lecturer, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan.

<sup>2</sup>Junior Associate Professor, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan.

<sup>3</sup>Assistant Professor, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan.

<sup>4</sup>Postgraduate Student, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan.

<sup>5</sup>Professor, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan.

**Correspondence to:** Dr Yuka I. Sumita, Department of Maxillofacial Prosthetics, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University (TMDU), 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8549, Japan. Fax: 03-5803-4757. Email: yuka.mfp@tmd.ac.jp

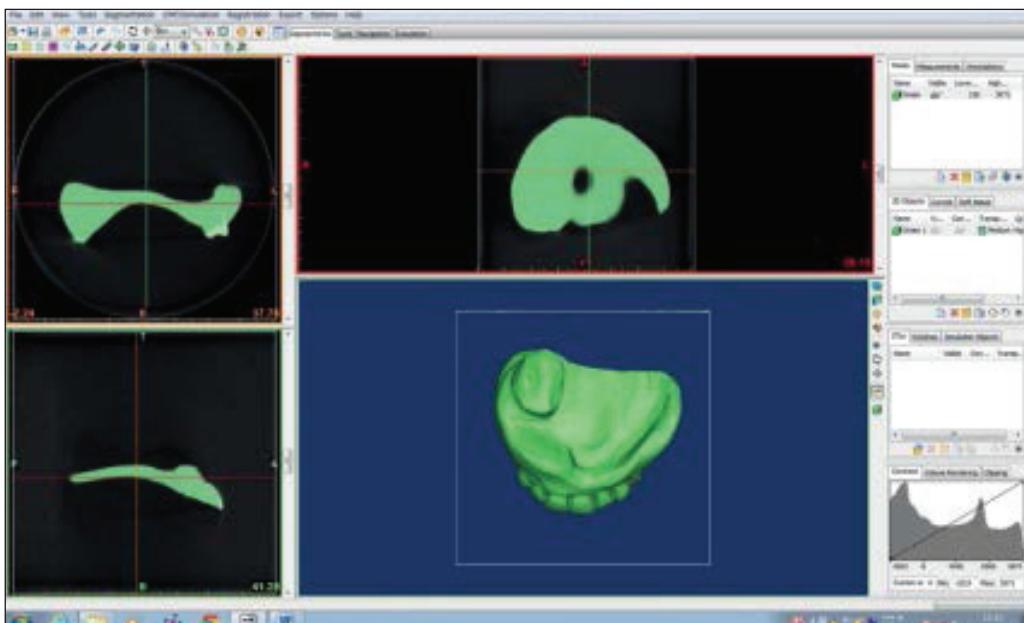
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**Fig 1** Intraoral view of the maxillectomy defect.



**Fig 2** The current obturator.



**Fig 3** The virtual 3D model of the obturator.



**Fig 4** The 3D-printed obturator.



**Fig 5** The definitive reproduced obturator.

printer (Portabee GO, Portabee) (Fig 4). The printed obturator was cleaned, and any excess supporting structures were removed from the surface. The 3D printed model was conventionally processed using self-curing acrylic resin (Unifast II, GC) for the teeth and heat-polymerized acrylic resin (Acron, GC) for

the base, then finished and polished in a conventional manner. The entire surface of the obturator was successfully scanned regardless of structural complexity, modeled as 3D data, printed in 3D, and conventionally manufactured. The definitive reproduced obturator (Fig 5) was successfully delivered and fitted to the



**Fig 6** The patient wearing her obturator.

patient's mouth at the second visit. Minor adjustment was needed to improve the retention. The patient was satisfied with her oral function and esthetics after she received her reproduced obturator (Fig 6).

## Discussion

This clinical report showed the feasibility of digital technology in the rapid reproduction of an obturator for a frail elderly maxillectomy patient. Advanced digital technology, including 3D scanning and printing, opens up the possibility of manufacturing maxillofacial prostheses more efficiently and with shorter lead times.<sup>3</sup> The advantage of using a CBCT scanner is that the obturator can be scanned rapidly while the patient is sitting in the dental chair, which shortens scanning time. Furthermore, the patient can walk out the clinic with the obturator. The definitive obturator can be delivered in the second visit to the clinic, ultimately reducing the number of visits.

Evidence of the clinical applicability of digital technology in the reproduction of obturators is limited to the present clinical report, and testing in a patient series is needed. Although the patient was edentulous

and the obturator was free of metallic objects, further studies involving partially dentate patients with metal clasp-retainer obturators need to be done as the CBCT will create noise and artifacts that will affect the quality of the scanned obturator and the virtual 3D model in such cases. As the obturator in this study was just proof of concept, the manufacturing material used was not standard dental material. More studies using 3D printable dental materials are needed. Further studies are needed to validate the feasibility of the presented method in a case series.

## Conclusions

This case report is a proof-of-concept study on the use of digital technology to rapidly reproduce an obturator for a frail elderly edentulous maxillectomy patient. It confirms the effectiveness of digitization in the reproduction of obturators that achieved satisfactory oral function and esthetics.

## Acknowledgments

This case report was presented at 16th Biennial Meeting of the International College of Prosthodontists, held in Seoul, Korea, from September 17 to September 20, 2015. The authors declare that there are no conflicts of interest regarding the publication of this paper.

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### Literature Abstract

#### The Evolution of TMD Diagnosis: Past, Present, Future

This article reviews the diagnosis process for temporomandibular disorders (TMD). In dentistry, diagnoses of TMD were made mainly focused on past structural issues associated with the oral cavity. Evidence-based practice was not common. The Research Diagnostic Criteria for TMD (RDC/TMD) were established using the fundamentals of biopsychosociology, strictly defining variables into measurable factors to enhance reliability, and the possibility of multiple diagnoses. These principles eventually evolved into the current diagnostic system—Diagnostic Criteria (DC/TMD). The complexity of this clinical issue was further studied based on etiology and biology. The authors summarized current and future research areas that may justify further improvement of the diagnostic criteria. The clinical implication of such effort is not clear at present.

**Ohrbach R, Dworkin SF.** *J Dent Res* 2016;1–9. **References:** 72. **Reprints:** R. Ohrbach, University at Buffalo, 355 Squire Hall, Buffalo, NY 14214, USA. Email: ohrbach@buffalo.edu —Ansgar C. Cheng, Singapore

# Does the Material Stiffness of Novel High-Performance Polymers for Fixed Partial Dentures Influence Their Biomechanical Behavior?

Ludger Keilig, Dr rer nat Dipl-Math<sup>1</sup>/Helmut Stark, Prof Dr med dent, DMD<sup>2</sup>/Christoph Bourauel, Prof Dr rer nat Dipl-Phys<sup>3</sup>

**Purpose:** To investigate the influence of framework materials with different elasticity moduli on the biomechanical performance of fixed partial dentures (FPDs). **Materials and Methods:** A tooth-anchored three-unit FPD and surrounding tissues were modeled in two variants (veneered/full anatomical FPD) and loaded on the central unit. Three different framework materials (titanium, zirconia, high-performance polymer) were simulated. **Results:** The polymer framework resulted in reduced framework stresses and increased veneering stresses. Varying the framework material had minimal influence on the loading of surrounding tissue. **Conclusions:** Using soft, novel materials as framework for dental FPDs does not negatively influence biomechanical loading of the involved biologic structures. *Int J Prosthodont* 2016;29:595–597. doi: 10.11607/ijp.4940

The many available framework materials cover a wide range of mechanical properties, from softer to more rigid, brittle to ductile, and vary in mechanical performance depending on these properties.<sup>1</sup> A recently introduced high-performance polymer (Pekkton ivory, Cendres+Métaux) for use as alternative framework material has a Young's modulus of approximately 5.1 GPa, considerably less stiff than titanium (typically 100 to 120 GPa, depending on the alloy), typical gold-based alloys (with a large range from < 90 GPa to > 130 GPa), or dental ceramics (60 to 450 GPa).<sup>2</sup> Studies on fixed partial denture (FPD) framework materials<sup>3,4</sup> seldom consider materials with such a low stiffness. It was the aim of this study to determine whether the decreased material stiffness of the high-performance polymer has an effect on the biomechanical behavior of a FPD made from this material using the finite element method (FEM).

## Materials and Methods

Finite element (FE) models of a FPD were generated using optical scans of an existing tooth-supported three-unit FPD. Separate scans of the framework, the veneered framework, and the tooth stumps were available. A tooth-supported FPD was chosen as the mobility of a natural anchor tooth is greater than the mobility of an implant, thus decreased stiffness of the FPD should have a larger influence with a tooth-supported FPD than with an implant-supported FPD. The geometry of the roots of the anchorage teeth were taken from a library of idealized teeth. Around the teeth, a 0.2-mm-thick layer of idealized periodontal ligament (PDL) was modeled. The resulting FE models of the FPD were loaded with a force up to 500 N in a 30-degree angle relative to the long axis of the teeth using a spherical indenter positioned directly above the central unit. The resulting model is shown in Fig 1. Depending on whether a veneered or a full anatomical FPD was simulated, veneering and framework were treated as separate materials that were glued together or as a single material without any separation in between.

Besides the new high-performance polymer, two different framework materials were used as idealized references: titanium Grade 5 (Young's modulus of 110 GPa), and zirconia (Young's modulus of 200 GPa). For all framework materials, two different geometries were considered, first a full anatomical FPD and then a veneered FPD. The properties of the materials used in the models can be found in Table 1. Material data for the cement and the veneering were chosen from

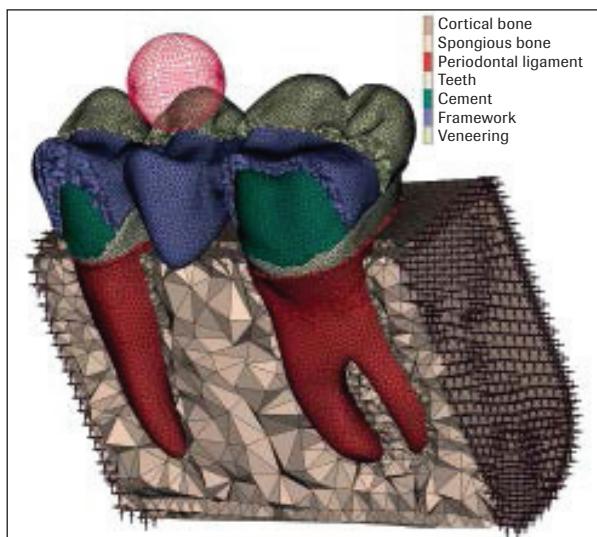
<sup>1</sup>Endowed Chair of Oral Technology and Department of Prosthetic Dentistry, Preclinical Education and Materials Science, Dental School, University of Bonn, Bonn, Germany.

<sup>2</sup>Head, Department of Prosthetic Dentistry, Preclinical Education and Materials Science, Dental School, University of Bonn, Bonn, Germany.

<sup>3</sup>Head, Endowed Chair of Oral Technology, Dental School, University of Bonn, Bonn, Germany.

**Correspondence to:** Dr Ludger Keilig, Endowed Chair of Oral Technologies, Welschnonnenstr 17, 53111 Bonn Dental School, University of Bonn, Bonn, Germany. Email: ludger.keilig@uni-bonn.de

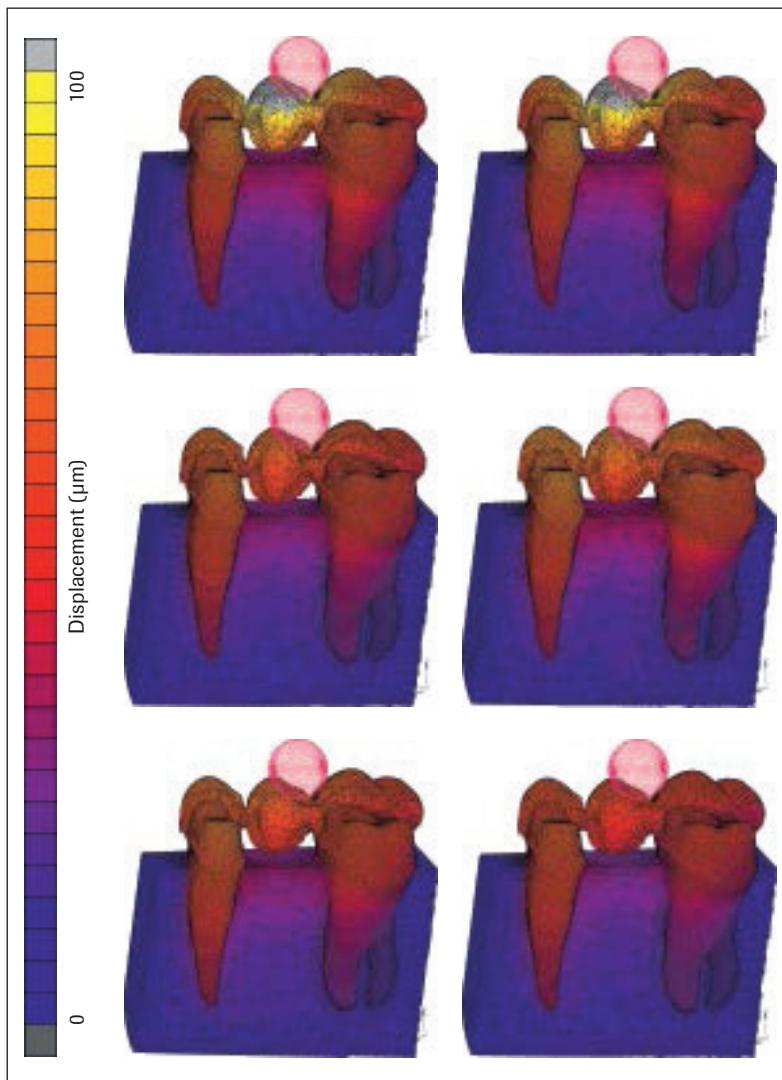
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**Fig 1** FE model of a tooth-supported three-unit FPD with a spherical indenter. Parts of the model were hidden to show the internal structure.

**Table 1** Material Parameters for Materials Used in the FE Simulations

Material	Young modulus (GPa)	Poisson ratio	Remarks
Cortical bone	18.00	0.30	
Spongy bone	0.30	0.30	
Periodontal ligament	0.05	0.45	
Teeth	20.00	0.30	Not differentiated
Cement	6.60	0.30	Used for the fixation of the FPD
Veneering	6.00	0.25	
Framework: Pekkton	5.10	0.25	Yield limit: approximately 120 MPa
Framework: Titanium Grade 5	110.00	0.30	Yield limit: approximately 800 MPa
Framework: Zirconia	200.00	0.30	Modulus of rupture: up to 1,000 MPa



**Fig 2** Color-coded representation of the calculated displacements in the whole model for veneered FPDs with framework made from high-performance polymer (top row), titanium (middle row), and zirconia (bottom row). The left column shows veneered FPDs, while the right column shows the corresponding full anatomical FPDs.

the material data sheets of the recommended cement and veneering for Pekkton ivory.

## Results

The calculated displacements within the whole model for the FPDs with different framework materials for veneered and full anatomical FPDs are shown in Fig 2. While the deflection of the loaded central unit of the FPD varies clearly with the framework material used (up to 0.30 mm for the full polymer FPD versus 0.07 mm for the full zirconia FPD; Fig 3), the resulting movement of the anchorage teeth shows only a minor influence of the framework material (from 0.06 mm to 0.08 mm for full zirconia and full Pekkton FPD, respectively).

Calculated stresses in the framework decreased with decreasing Young's modulus (Fig 4). Stresses in the veneered framework were higher than in the full anatomical framework made from the same material due to the reduced framework dimension. Stresses in the veneering, on the other hand, increased with decreasing Young modulus. Stresses in the veneering of the polymer FPD between the units in particular reached unfavorable high values.

## Discussion

The performed simulations have shown that the stiffness of the framework material of a three-unit FPD does not excessively influence the biomechanical loading of the involved anatomical structures. While the materials used for the reference FPDs do not correspond to specific materials, these idealizations still give a realistic overview of available, commonly used materials.

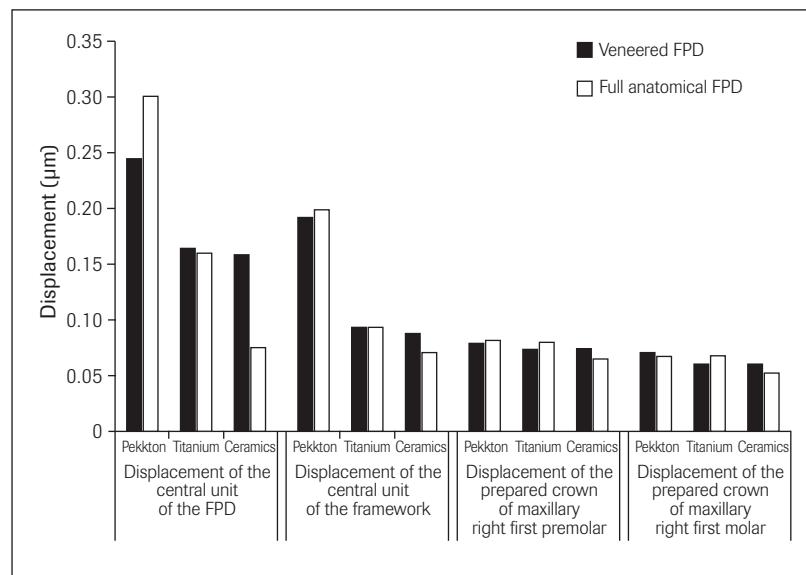
Due to the increased stresses in the veneering of the polymer FPD, it seems reasonable to either use full anatomical FPDs or veneer each unit separately to avoid damage to the veneering in this area.

## Acknowledgments

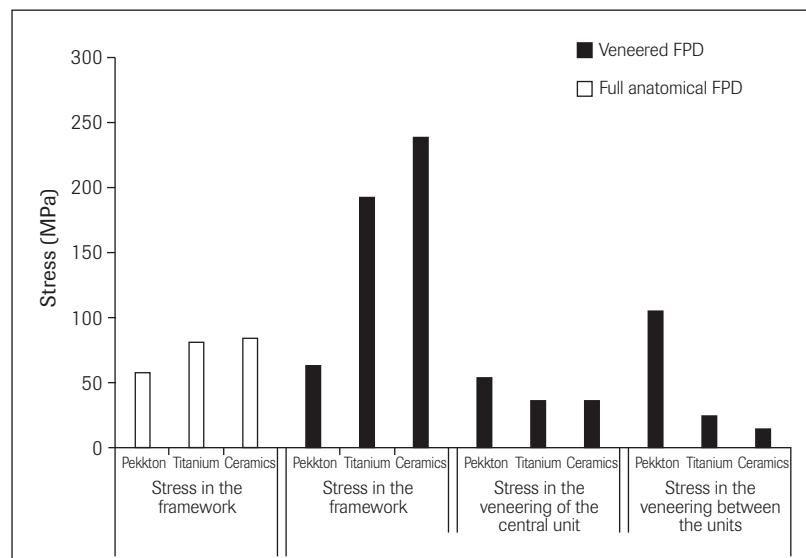
The authors would like to thank Cendres+Métaux SA for providing material data for the polymer and scan data for the FPD. The authors reported no conflicts of interest related to this study.

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**Fig 3** Comparison of the maximum displacement determined in different parts of the model.



**Fig 4** Calculated maximum stresses in various parts of the FPDs determined in different FPDs.

# A Case Series Treatment Outcome Report Following 5 Years of Implant Overdenture Treatment

Stavros Pelekanos, DDS, Dr Med Dent<sup>1</sup>/Aspasia Sarafianou, DDS, PhD<sup>2</sup>/Panagiotis Tsirogiannis, DDS<sup>3</sup>/Phophi Kamposiora, DDS, MSc, PhD<sup>1</sup>/Georgios Papavasiliou, DDS, MSc, PhD<sup>1</sup>

**Purpose:** To assess clinical performance of bar-retained implant overdentures (IOs) with distally placed ERA attachments on four implants, and patient satisfaction after a follow-up period of 5 years in a convenience selection of 15 patients. **Materials and Methods:** Bar-retained IOs with distally placed ERA attachments were placed and clinically monitored. Encountered complications during a 5-year follow-up period were recorded; and a modified OHIP-14 questionnaire was used to assess patient satisfaction. **Results:** Implant and restoration survival rates of 97.5% and 100%, respectively, were recorded. The most common maintenance requirement was the replacement of ERA retentive elements. A high degree of patient satisfaction was reported. **Conclusions:** The proposed IO design is a reliable clinical treatment protocol associated with a high degree of patient satisfaction and minor prosthetic complications. *Int J Prosthodont* 2016;29:598–601. doi: 10.11607/ijp.4787

Increased residual ridge reduction and associated prosthetic retention needs underscore the merit of prescribing mandibular and maxillary bar-retained implant overdentures (IOs) on four or more implants.<sup>1,2</sup> Retention may be increased via distal bar segment cantilevers or by combining the bar with different attachments (ie, distally placed ERA attachments), leading to increased patient comfort, better chewing ability, and improvement in quality of life.<sup>1,2</sup> However, this treatment option may also be associated with clinical maintenance complications, such as peri-implant tissue inflammation, mucosal hyperplasia, attachment loosening, and overdenture base fractures.<sup>3</sup>

The objective of this report is to describe our 5-year clinical experience with managing treatment outcomes in a convenience sample of 10 patients who wore IOs retained and supported by bars placed on four implants, with distally placed ERAs.

## Materials and Methods

A convenience sample of 15 patients (5 women and 10 men; aged between 56 and 78 years, mean age: 62 years) was selected for the case series. The patients were edentulous in at least one jaw for at least a year and had been wearing complete dentures for at least 9 months, with recorded problems of prosthesis stability and retention. Following extensive patient consultation regarding treatment options, a clinical management protocol was confirmed and four implants were placed in either the anterior maxilla or the interforaminal mandibular area to support bar-retained overdentures.

Exclusion criteria included brittle diabetes, smoking, history of head and neck radiotherapy, need for bone grafting, and previous implant surgery. The implants were to be placed in native bone, and the selection of implant sites was prosthetically driven. For this reason, patients with bone features or arch morphology not allowing adequate distance between the two central implants to accommodate the retentive clip were excluded. Before treatment, all patients were asked to complete a modified Oral Health Impact Profile (OHIP) questionnaire (Table 1).

The implants were placed between December 2007 and November 2008 and the patients were followed up until November 2013 (mean follow-up time: 4.9 years). During the follow-up period, two patients relocated to another city, another two stopped showing up for recalls, and one was deceased. The final sample consisted of 10 patients, 6 men and 4 women.

<sup>1</sup>Assistant Professor, Department of Prosthodontics, University of Athens Dental School, Athens, Greece.

<sup>2</sup>Lecturer, Department of Prosthodontics, University of Athens Dental School, Athens, Greece.

<sup>3</sup>Postgraduate Student, Department of Prosthetic Dentistry, University of Hamburg-Eppendorf, Hamburg, Germany.

**Correspondence to:** Dr Pelekanos Stavros, Department of Prosthodontics, University of Athens Dental School, El Venizelou Str 163b, 176 72 Athens, Greece. Email: pelekan@otenet.gr

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	Round bar			Hader			Dolder			Milled
	Plastic clip	Rider	Rider with spacer	Plastic clip	Rider	Rider with spacer	Pear shaped	Pear with spacer	U-shaped	0, 2, 4 degrees
Vertical movement	No	No	Yes	No	No	Yes	No	Yes	No	No
Rotation	Yes	No	No							
Support	Rigid or combined	Rigid	Rigid							
Reciprocation	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

**Fig 1** A classification of commercially available bar types. From left to right: round, Hader, Dolder, and milled bar patrix sections. The section configuration of the patrix bar part, along with the type of the matrix (plastic clips and riders with or without spacers), dictates the type and extent of allowed IO movement (vertical movement, rotation), the nature of the IO support (rigid or mixed), and the presence of reciprocation.

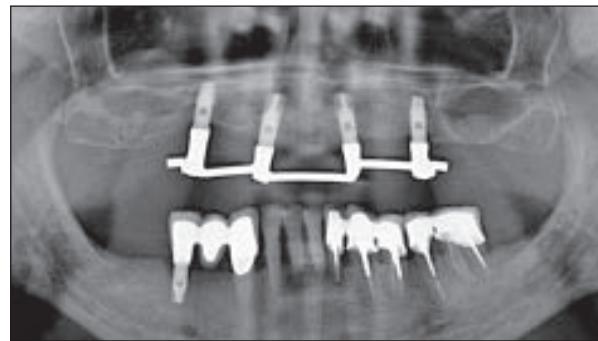
**Table 1** The Modified OHIP-14 and the Patient Assessment Questionnaire Used

Oral Health Impact Profile	Score
Have you had trouble during speech because of problems with your mouth or dentures?	
Have you felt that your taste has deteriorated because of problems with your mouth or dentures?	
Have you experienced pain in your mouth?	
Have you felt uncomfortable when masticating because of problems with your mouth or dentures?	
Have you been self-conscious because of your mouth or dentures?	
Have you felt tense because of problems with your mouth or dentures?	
Has your diet been unsatisfactory because of problems with your mouth or dentures?	
Have you had to interrupt meals because of problems with your mouth or dentures?	
Did you have difficulties in relaxing because of problems with your mouth or dentures?	
Have you felt embarrassed because of problems with your mouth or dentures?	
Have you been irritable with other people because of problems with your mouth or dentures?	
Have you had difficulties doing your usual jobs because of problems with your mouth or dentures?	
Have you felt that life in general was less satisfying because of problems with your mouth or dentures?	
Have you been totally unable to function because of problems with your mouth or dentures?	
Constantly = 0; Very often = 1; Fairly often = 2; Occasionally = 3; Hardly ever = 4; Never = 5	

#### Patient Assessment

What is your general opinion concerning your new prosthesis?	
How well does your new prosthesis stay in place?	
How well can you talk with your new prosthesis?	
How easy is it for you to perform daily oral hygiene?	
How would you rate your appearance in regard to your prosthesis?	
How satisfied are you with the maintenance procedures and costs?	

Not satisfied = 0; Average = 5; Very satisfied = 10

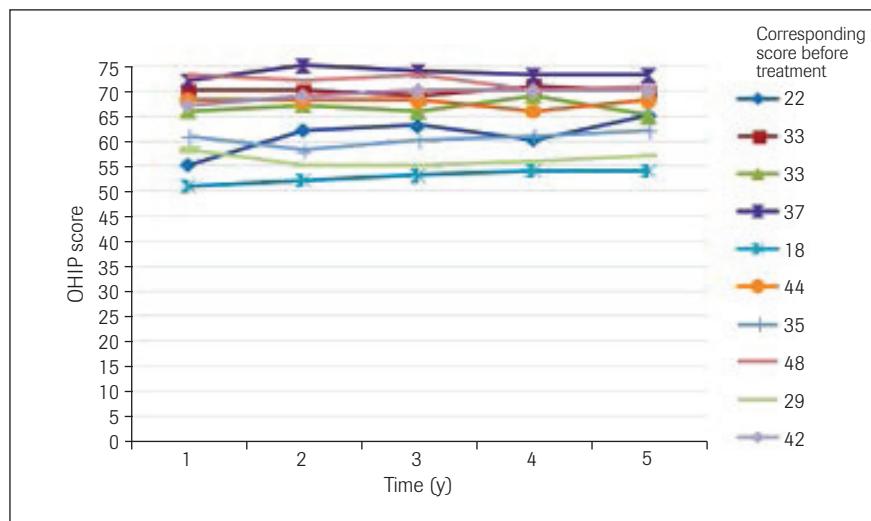


**Fig 2** Panoramic radiograph of a patient with four implants in the anterior maxilla, connected with a bar attachment with distal ERAs.



**Fig 3** Completed cast round bar attachment connected to four implant analogs on the IO master cast. Note the two distal ERA matrices positioned at the distal bar ends.

Four implants (Biomet 3i) were placed in the edentulous jaw of each of the 10 participating patients, anterior to the sinus or the mental foraminae. At the end of the osseointegration period, bar-retained implant-supported overdentures were fabricated. A round-section bar (round bar with rider, Cendres+Métaux) was used. Distal ERA attachments (Stern ERA, APM-Sterngold) offered additional retention and vertical resiliency (Figs 1 to 3).



**Fig 4** The annual OHIP scores of the participating patients.

**Table 2a** Mean and SD OHIP-14 Scores at the End of the 5-Year Observation Period

OHIP	
Valid (n)	60
Missing (n)	0
Mean	59.80
SD	13.663

**Table 2b** Mean and SD Patient Assessment Scores at the End of the 5-Year Observation Period

Patient assessment	
Valid (n)	50
Missing (n)	10
Mean	49.3000
SD	3.51817

**Table 2c** Kruskal Wallis Test. Grouping Variable: Year

	OHIP	Patient assessment
Chi-square	24.851	12.252
df	5	4
Asymptomatic significance	.000	.016

Patients were placed on a 3-month recall schedule. IO retention and occlusion, the need for relining, the peri-implant tissue condition, and oral hygiene were evaluated. Patients rated their satisfaction of the prosthesis annually using a modified OHIP-14 questionnaire and a patient assessment questionnaire (Table 1). After 5 years of clinical service, all data were collected and Kruskall-Wallis test (SPSS Statistics, IBM) was used for statistical analysis ( $P < .05$ ).

## Results

The most common adjustment was replacement of the retentive elements of the ERA attachments (50%). One IO had to be modified by replacement of the acrylic teeth due to excessive wear.

One implant failure was recorded 3 years after placement (implant survival rate: 97.5%). Mucosal hyperplasia was clinically detected under one bar attachment (10% of cases). Inflammation of the peri-implant tissues with a probing depth of 5 mm was recorded around one implant in another patient.

According to the OHIP-14 questionnaire, patients expressed high satisfaction levels and an improvement was found in their general quality of life (Table 2 and Fig 4). All patients expressed satisfaction regarding retention and stability of the prosthesis. A mean OHIP score of 59.8 out of 70 and a mean patient assessment score of 49.3 out of 60 were recorded, which can be described as completely satisfactory (Tables 2a and 2b). A statistically significant difference among the annual OHIP scores and among the annual patient assessment scores was also found at  $P < .05$  (Table 2c).

## Discussion

The 100% prostheses survival rate and the minimal prosthetic complications recorded in the present case, with the most common incident being replacement of the ERA attachment males (50%), are in accordance with the literature (Table 3).<sup>2-5</sup> Efficient oral hygiene and adequate distance between the bar and the oral mucosa are essential for prevention of mucosal hyperplasia, which was reported for one patient.

The 97.5% implant survival rate recorded over 5 years is in accordance with the limited number of studies evaluating specific designs.<sup>2-4,6</sup> Answers to the OHIP-14 questionnaire indicate an improvement in patients' quality of life, while the overdenture design was positively evaluated (Table 3).

**Table 3** Comparison of the Findings of Recent Studies on IOs to Those of the Present Report

Study	Patients (n)	Implants per IO (n)	Mx/Md	Splinted/unsplinted	Follow-up period (y)	Implant survival (%)	Restoration survival (%)	Prosthetic complications	Patient satisfaction
Present report	10	4	Mx and Md	Splinted	5	97.5	100	Replacement of retentive elements (ERA males), gingival hyperplasia, replacement of acrylic teeth	High
Heschl et al <sup>4</sup>	39	4	Md	Splinted	5	99.4	100	Acrylic teeth fractures, bar fractures	
Raghoebar et al <sup>2</sup>		≤ 4	Mx	Splinted		97/y	96.9/y		
Bilhan et al <sup>3</sup>	8	4	Md	Splinted	1	100	100	Adjustments, repairs	
Martin-Ares et al <sup>5</sup>	50	4	Mx and Md	Not reported					High (36%), average (38%)
Slot et al <sup>6</sup>	50	6	Mx	Splinted	1	99.3–98.0	100		High

The reported high levels of satisfaction with prosthesis stability could be largely attributed to the increased retention provided by the combination of bar and ERA attachments. The presence of a metal bar rider with spacer, combined with ERA attachments of 0.4-mm resiliency, allowed vertical movement of the IO, while the round section of the bar allowed rotational movement, resulting in an implant-mucosa-supported prosthesis (combined support) (Fig 1).

Limitations of this case history series report include the limited sample size and the inclusion of both maxillary and mandibular IOs. Further research, especially in the form of prospective clinical trials, is needed for an in-depth evaluation of this specific IO design.

## Conclusions

Various overdenture designs proposed in the literature, involving either splinted or nonsplinted implants, are associated with high implant and restoration survival rates and increased patient satisfaction. The present case history series suggests that IOs on four implants retained by bars with distal ERAs permit a reliable treatment protocol associated with a high degree of patient satisfaction. The observed clinical outcomes are comparable to other designs presented in the literature.

## Acknowledgments

The authors reported no conflicts of interest related to this study.

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# Fit of e.max Crowns Fabricated Using Conventional and CAD/CAM Technology: A Comparative Study

Atsushi Miwa, DDS, PhD<sup>1</sup>/Hidehiro Kori, DDS, PhD<sup>2</sup>/Yoshihiro Tsukiyama, DDS, PhD<sup>3</sup>/Rika Kuwatsuru, DDS, PhD<sup>4</sup>/Yasuyuki Matsushita, DDS, PhD<sup>3</sup>/Kiyoshi Koyano, DDS, PhD<sup>5</sup>

**Purpose:** The aim of this study was to examine the fit accuracy of e.max crowns by investigating marginal and internal gaps. **Materials and Methods:** In experiment 1, 60 e.max computer aided design/computer-assisted manufacture (CAD/CAM) crowns were manufactured. The crowns were fabricated using optical scanning of artificial teeth (Op group) or scanning of a plaster model following a silicone impression (M group). Cement space settings of 90, 120, and 150 µm were applied. Marginal and internal crown gaps were compared among six conditions (Op90, Op120, Op150, M90, M120, M150). In experiment 2, e.max CAD crowns from the Op group (CADop group) and the M group (CADm group) were compared with e.max Press crowns (Press group) by measuring marginal and internal gaps of the crowns using Scheffe multiple comparison test. The level of significance was set at .05. **Results:** In experiment 1, the marginal gap of the Op90 group was significantly higher than that of the Op120 and Op150 groups. The marginal gap of the M90 group was significantly higher than those of the M120 and M150 groups, and the internal gap of the M90 group was significantly lower than that of the M150 group. Although there was no statistically significant difference in marginal gap among the three groups, the internal gap of the CADm group was significantly higher than the Press group. **Conclusion:** Although the variation in cement space settings and fabrication techniques affected accuracy, e.max CAD crowns fabricated using optical scanning of melamine teeth achieved a clinically acceptable fit. *Int J Prosthodont* 2016;29:602–607. doi: 10.11607/jp.4865

Restorations using metal, such as metal-cast crowns and porcelain-fused-to-metal crowns, traditionally have been used because of their high mechanical strength. With increased esthetic demand, risk of metal allergy, and increased cost of metal, metal-free restorations have become more common. In particular, e.max has attracted attention as an excellent esthetic material with satisfactory mechanical strength for fabricating all-ceramic crowns.<sup>1–17</sup>

Recently, computer-aided design/computer-assisted manufacture (CAD/CAM) technology has been generally incorporated into clinical practice.<sup>18,19</sup> Fabricating crowns using CAD/CAM technology can reduce complicated laboratory procedures and therefore time and cost.<sup>18</sup> Use of the direct optical impression technique<sup>1,5,9,11,18,20,21,26</sup> would also improve clinical procedures by avoiding conventional impression techniques, which are often unpleasant for patients.

The accuracy of a prosthesis is an important factor associated with the prognosis of the abutment teeth.<sup>1–3,6,22</sup> Ill-fitting crowns may cause caries and periodontal disease. A large marginal gap may result in the collapse and washout of the luting cement layer, marginal microleakage of intraoral bacteria, and detachment of the crown.<sup>22</sup> Marginal gap, therefore, is particularly important,<sup>2,3,22</sup> and a marginal gap greater than 100 µm is considered clinically unacceptable.<sup>7,22–26</sup> The accuracy of restorations fabricated via CAD/CAM technology has been a major issue.

CAD/CAM technology has evolved, and the accuracy of all-ceramic crowns fabricated using the latest CAD/CAM technology has not been fully investigated. The purpose of this study was to investigate the marginal gap of all-ceramic crowns fabricated using the latest CAD/CAM technology with different impression

<sup>1</sup>Research Fellow, Section of Implant and Rehabilitative Dentistry, Division of Oral Rehabilitation, Faculty of Dental Science, Kyushu University, Fukuoka, Japan.

<sup>2</sup>Private Practice, Fukuoka, Japan.

<sup>3</sup>Associate Professor, Section of Implant and Rehabilitative Dentistry, Division of Oral Rehabilitation, Faculty of Dental Science, Kyushu University, Fukuoka, Japan.

<sup>4</sup>Assistant Professor, Section of Implant and Rehabilitative Dentistry, Division of Oral Rehabilitation, Faculty of Dental Science, Kyushu University, Fukuoka, Japan.

<sup>5</sup>Professor and Chairman, Section of Implant and Rehabilitative Dentistry, Division of Oral Rehabilitation, Faculty of Dental Science, Kyushu University, Fukuoka, Japan.

**Correspondence to:** Dr Yoshihiro Tsukiyama, Section of Implant and Rehabilitative Dentistry, Division of Oral Rehabilitation, Faculty of Dental Science, Kyushu University 3-1-1 Maidashi, Higashi-ku, Fukuoka, 812-8582 Japan. Fax: +81-92-642-6380. Email: Tsuki@dent.kushu-u.ac.jp

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or scanning methods. The marginal and internal gaps of e.max CAD/CAM crowns fabricated by direct optical impression or by scanning plaster models using the CEREC AC Omnicam were compared with e.max Press crowns made by a dental technician.

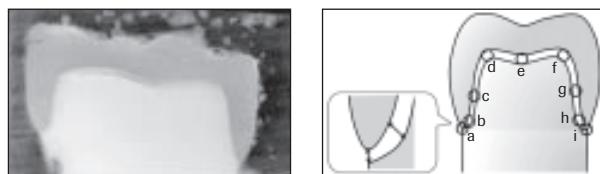
## Materials and Methods

### Experiment 1

A total of 60 custom-made melamine abutment teeth prepared for fabricating e.max CAD crowns in the maxillary left first molar (A262, Nissin) were used to standardize the tooth preparation. The crowns were divided into two groups of 30 each: those fabricated by optical impression of the abutment teeth (Op group), and those fabricated by scanning abutment teeth on a plaster model (M group).

For the Op group, the artificial teeth were mounted on a jaw model (D51D-QD.P8, Nissin), and optical impressions were performed using a CAD/CAM device (CEREC AC Omnicam, Sirona Dental Systems). e.max CAD crowns were shaved from e.max blocks by a CAM machine (CEREC MC XL, Sirona Dental Systems) with cement space settings of 90, 120, or 150  $\mu\text{m}$ . A total of 10 e.max CAD crowns were fabricated for each cement space setting (Op90, Op120, Op150). The crowns were fired using an e.max furnace (Programat, Ivoclar Vivadent). For the M group, silicone impressions (Fusion II Monophase/Extrawash, GC) of the maxillary left first molars were taken, and plaster models (New Fujirock, GC) were made. The plaster models were scanned using a CAD/CAM device (CEREC AC Omnicam, Sirona Dental Systems), and 10 e.max CAD crowns were fabricated for each cement space setting (M90, M120, M150) using the same method as in the Op group.

The manufactured crowns were attached to melamine abutment teeth using an adhesive resin cement (Clearfil SA Luting, Kuraray) with the constant load of 2 kgf pressure using the precision universal testing machine (Autograph, Shimadzu). The test specimens were cross-sectioned in the mesiodistal direction through the center of the occlusal surface using a diamond saw (Exakt, Meiwa Fosis).<sup>2-4,11-13,15,16,19,20,22,23,25,27,28,33</sup> Cross sections were made following the same path for all crowns using jigs made of autopolymerized resin (Tray resin II, Shofu). The thickness of the cement layer was measured at nine points, shown in Fig 1 as a to i, using an optical microscope (Biorevo, Keyence). The marginal gap (the thickness of the cement layer at the crown margin) was determined using the average values of a and i (Fig 1). The internal gap (the inner cement layer thickness) was determined using the average value of



**Fig 1** Cross section of specimen and measurement points for cement layer thickness.

b to h (Fig 1). Marginal and internal crown gaps were compared for the six conditions (Op90, Op120, Op150, M90, M120, and M150).

### Experiment 2

According to the results of experiment 1, the group that showed the smallest marginal and internal gap among the Op90, Op120, and Op150 groups was defined as the CADop group. The group that exhibited modest marginal and internal gap among M90, M120, and M150 was defined as the CADm group. In addition, silicone impressions were taken of artificial molar teeth mounted on the jaw model, and plaster models were fabricated. A dental technician with 10 years of experience then fabricated e.max Press crowns using an e.max ingot and the e.max furnace (Programat, Ivoclar Vivadent). Test specimens were made for e.max Press crowns (Press group) and marginal and internal gaps were measured using the same method as in experiment 1. Marginal and internal crown gaps were compared among the three conditions (CADop, CADm, and Press).

### Statistical Analysis

Marginal and internal gaps were compared using Scheffe multiple comparison test among Op90, Op120, and Op150 groups; among M90, M120, and M150 groups; and among CADop, CADm, and Press groups. Statistical analysis was performed using SPSS Statistics 22 (IBM), and the level of significance was set at  $P < .05$ .

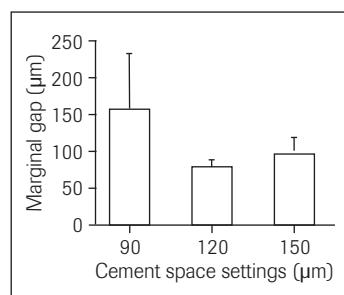
## Results

The marginal and internal gaps for Op90, Op120, Op150, M90, M120, and M150 groups are presented in Table 1 and Figs 2 to 5.

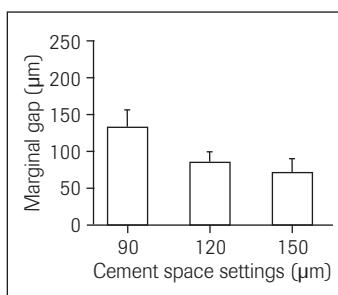
The marginal gap for the Op90 group was significantly higher than that of the Op120 and Op150 groups (Op90–Op120,  $P = .002$ ; Op90–Op150,  $P = .022$ ; Op120–Op150,  $P = .663$ ; Scheffe multiple comparison test). The maximum marginal gap was seen in the Op90 group (328  $\mu\text{m}$ ), and the minimum was obtained in the Op120 group (49  $\mu\text{m}$ ). While the marginal gap of

**Table 1** Marginal Gap and Internal Gap for e.max CAD Groups

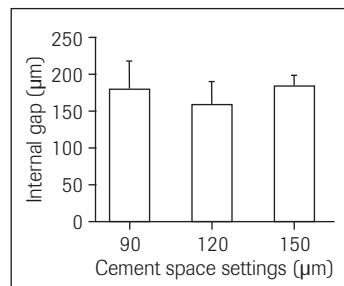
Group	Setting value of cement space ( $\mu\text{m}$ )	n	Marginal gap ( $\mu\text{m}$ )		Internal gap ( $\mu\text{m}$ )			
			Range	Mean	SD	Range	Mean	
CADop	90	10	75–328	157	76	129–256	180	38
	120	10	49–92	77	11	139–222	161	30
	150	10	72–125	96	18	167–207	184	15
CADm	90	10	98–177	134	23	142–196	167	23
	120	10	62–112	84	16	152–232	186	24
	150	10	48–102	72	17	165–281	208	37



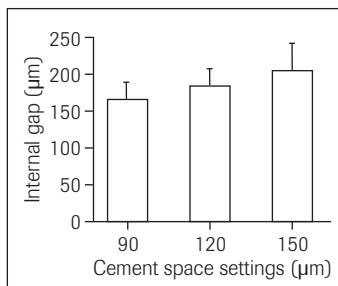
**Fig 2** Marginal gap for Op group in experiment 1. Marginal gap for Op90 group was significantly higher than that for Op120 and Op150 groups (Op90–Op120,  $P = .002$ ; Op90–Op150,  $P = .022$ ; Op120–Op150,  $P = .663$ ; Scheffe multiple comparison test).



**Fig 3** Marginal gap for M group in experiment 1. The marginal gap for M90 group was significantly higher than that for M120 and M150 groups (M90–M120,  $P < .001$ ; M90–M150,  $P < .001$ ; M120–M150,  $P = .399$ ; Scheffe multiple comparison test).



**Fig 4** Internal gap for Op group in experiment 1. There was no statistically significant difference in the internal gap among the three groups (Op90–Op120,  $P = .384$ ; Op90–Op150,  $P = .947$ ; Op120–Op150,  $P = .238$ ; Scheffe multiple comparison test).



**Fig 5** Internal gap for M group in experiment 1. The internal gap for the M90 group was significantly lower than that for the M150 group (M90–M120,  $P = .346$ ; M90–M150,  $P = .014$ ; M120–M150,  $P = .259$ ; Scheffe's multiple comparison test).

all specimens for the Op120 group was  $< 100 \mu\text{m}$ , the number of specimens in which the marginal gap was  $< 100 \mu\text{m}$  was 1 for the Op90 group and 6 for the Op150 group. The standard deviation for the Op90 group was the highest among the three groups. Although the internal gap for the Op120 group was the lowest, there was no statistically significant difference among the three groups (Op90–Op120,  $P = .384$ ; Op90–Op150,  $P = .947$ ; Op120–Op150,  $P = .238$ ; Scheffe multiple comparison test).

The marginal gap for the M90 group was significantly higher than that for the M120 and M150 groups (M90–M120,  $P < .001$ ; M90–M150,  $P < .000$ ; M120–M150,  $P = .399$ ; Scheffe multiple comparison test). The maximum marginal gap was seen in the M90 group (177  $\mu\text{m}$ ), and the minimum marginal gap was obtained in the M150 group (48  $\mu\text{m}$ ). The number of specimens in which the marginal gap was  $< 100 \mu\text{m}$  was 1 for the M90 group, 9 for the M120 group, and 9 for the M150 group. The internal gap for the M90 group was significantly lower than that for the M150 group (M90–M120,  $P = .346$ ; M90–M150,  $P = .014$ ; M120–M150,  $P = .259$ ; Scheffe multiple comparison test). The M90 group exhibited the smallest internal gap.

According to the results of experiment 1, Op120 was defined as the CADop group because it showed the lowest marginal gap without a significant internal gap among the three conditions. For the M group, M120 was defined as the CADm group since it exhibited the most modest marginal and internal gap among the three conditions. The marginal and internal gaps for the CADop, CADm, and Press groups are presented in Table 2 and Figs 6 and 7.

The marginal gap for the CADop group was the lowest, but there was no statistically significant difference among the three groups (CADop–CADm,  $P = .628$ ; CADop–Press,  $P = .501$ ; CADm–Press,  $P = .977$ ; Scheffe multiple comparison test). The maximum marginal gap was seen in the Press group (117  $\mu\text{m}$ ), and the minimum marginal gap was obtained in the CADop group (49  $\mu\text{m}$ ). While the marginal gap for all specimens for the CADop group was  $< 100 \mu\text{m}$ , the number of specimens in which the marginal gap was  $< 100 \mu\text{m}$  was 9 for the CADm group and 7 for the Press group.

The internal gap for the CADm group was significantly higher than that for the Press group (CADop–CADm,  $P = .437$ ; CADop–press,  $P = .501$ ; CADm–press,  $P = .047$ ; Scheffe multiple comparison test). The maximum internal gap (278  $\mu\text{m}$ ) and the minimum internal gap (68  $\mu\text{m}$ ) were seen in the Press group. The standard deviation for the Press group was the highest among the three groups.

## Discussion

The marginal and internal gaps of e.max crowns fabricated under different conditions were compared in the present study. The CEREC system, which has been widely used, was selected as the CAD/CAM device.

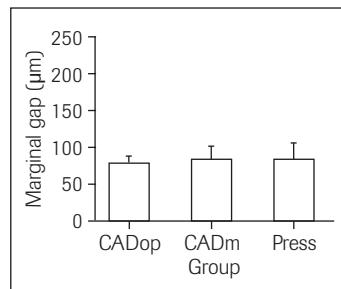
The cement space settings of the CAD/CAM system can influence the accuracy of crowns.<sup>11,29</sup> The accuracy of the crowns was investigated in the Op and M groups to determine the optimal cement space setting for each fabricating method. Cement space settings of 90, 120, and 150 µm, which are used clinically for the CEREC system, were investigated.

Although there was no statistically significant difference in the internal gap among the three groups, the marginal gap for the Op120 group was smaller than those for the Op90 and Op150 groups, and the marginal gap of all specimens for the Op120 group was < 100 µm. These results differed from those reported in a previous study in which the marginal gap of crowns decreased as the cement space setting increased.<sup>29</sup> It is possible that crowns of the Op150 groups became displaced from the preset position against the abutment teeth, determined in the CAD planning process, if the internal fit was too loose.

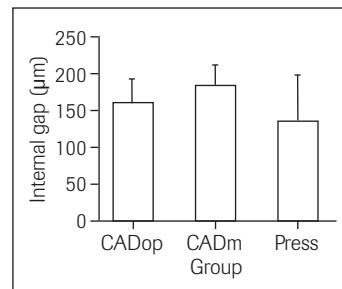
Among the M groups, the marginal gap in the M150 group was the lowest, which was consistent with a previous study in which the marginal gap of crowns decreased as the cement space setting increased.<sup>29</sup> The effect of the cement space setting value could be pronounced in the M groups, because the error during the optical impression of the plaster abutment teeth was minimal compared with that for the melamine artificial teeth. The internal gap for the M90 group was smaller than those for the M120 and M150 groups. The M150 group exhibited the largest internal gap, although there was no statistical difference between the M120 and M150 groups. These results were anticipated given that the internal gap of the crowns increased as the cement space setting value increased. Taking these results for marginal and internal gaps into account, M120 was defined as the CADm group.

**Table 2** Marginal Gap and Internal Gap for e.max CAD Groups and e.max Press Group

Group	Setting value of cement space (µm)	n	Marginal gap (µm)			Internal gap (µm)		
			Range	Mean	SD	Range	Mean	SD
CADop	120	10	49–92	77	11	139–222	161	30
CADm	120	10	62–112	84	16	152–232	186	24
Press	–	10	66–117	86	19	68–278	136	63



**Fig 6** Marginal gap in experiment 2. There was no statistically significant difference in the marginal gap among the three groups (CADop–CADm,  $P = .628$ ; CADop–Press,  $P = .501$ ; CADm–Press,  $P = .977$ ; Scheffe multiple comparison test).



**Fig 7** Internal gap in experiment 2. The internal gap for the CADm group was significantly higher than that for the Press group (CADop–CADm,  $P = .437$ ; CADop–Press,  $P = .501$ ; CADm–Press,  $P = .047$ ; Scheffe multiple comparison test).

In this experiment, the marginal gap was larger when the cement space setting was 90 µm for both Op and M groups. The increased marginal gap could be due to the decrease in the flow of cement resulting in elevation of the crown. For cement space settings of 120 and 150 µm, however, no significant differences in the marginal gap were observed. In addition, no significant difference was observed in the internal gap for the Op group, while significant difference was observed for the M group. The obtained results should be carefully interpreted because the present study used *in vitro* experiments with limited conditions.

The average marginal gaps for the CADop, CADm, and Press groups were < 100 µm, suggesting that clinically acceptable accuracy of the e.max crowns was obtained by all three methods (optical direct impression, model scanning impression, and the Press technique by a dental technician) in terms of the fit of the crown margins.

The marginal gap of all specimens for the CADop group was < 100 µm, indicating that the optical direct impression could be considered the most appropriate method in terms of the marginal gap. The procedure for this method is simple compared with the model scanning technique or the Press technique, because errors in impression taking and making plaster models can be excluded. However, the results were based on optimal conditions for direct optical impressions, and the accuracy might be influenced by conditions such as moisture, gingival crevicular fluid, or bleeding in clinical situations. In the CADm group, although the marginal gap of nine specimens was < 100 µm, the internal gap was significantly larger than in the Press group. This indicates that the

poorer internal fit of crowns might increase the possibility of problems such as collapse of the luting cement layer and fracture or detachment of crowns.<sup>22</sup> Three crowns in the Press group had a marginal gap  $> 100 \mu\text{m}$ . Although the average internal gap of the Press group was the lowest among the three methods, the variation was relatively high. Technical errors that could occur in every procedure for fabricating e.max Press crowns might have affected the variation in marginal and internal gaps.

Because this investigation into the accuracy of e.max crowns used artificial teeth, the results may not reflect the outcome in clinical situations. Difficult situations such as bleeding, moisture, and limited mouth opening during direct optical scanning could result in poor accuracy of CAD/CAM crowns. Differences in tooth preparation, luting cement, materials for restoration, and CAD/CAM system used could also affect the results. Further research under different conditions is required. Taking these limitations into account, the present study revealed that e.max CAD crowns fabricated using direct optical impressions of melamine abutment teeth or by scanning plaster model abutment teeth resulted in crowns with clinically acceptable accuracy.

## Conclusions

This study investigated the accuracy of e.max CAD crowns using CEREC AC Omnicam and e.max Press crowns, and revealed the following results:

1. The Op120 group showed clinically acceptable marginal gap.
2. The M150 group showed the smallest marginal gap and the highest internal gap. The M120 group showed the most modest marginal and internal gap.
3. No statistically significant difference in the marginal gap was observed among the CADop, CADm, and Press groups, and the marginal gap for these three groups was considered clinically acceptable.
4. The overall marginal gap of the CADm and Press groups was considered clinically acceptable although one and three specimens with a marginal gap  $> 100 \mu\text{m}$  were observed in each group.
5. The e.max CAD crowns fabricated using the CAD/CAM system showed clinically acceptable accuracy.

## Acknowledgments

The authors thank J. Morita Corporation for lending the CAD/CAM device (CEREC AC Omnicam and CEREC MC XL) and NK Dental Craft for fabricating the e.max Press crowns. The authors reported no conflicts of interest related to this study.

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#### *Literature Abstract*

#### **Outcomes of an Oral Care Protocol in Postmechanically Ventilated Patients**

This prospective randomized controlled trial focused on hospitalized patients receiving extubation to determine the impact of an intervention protocol that included twice-daily tooth brushing, tongue scraping, flossing, mouth rinsing, and lip care on health outcomes. Major outcome measures were the revised THROAT (R-THROAT; oral cavity assessment) and rate of oral colonization of methicillin-sensitive *Staphylococcus aureus* (MSSA) and methicillin-resistant *S aureus* (MRSA), patient satisfaction, and symptom burden assessment. A total of 74 subjects were randomized into two groups (usual care group vs intervention group). As measured by the R-THROAT, oral cavity health improved over time in both groups. However, the intervention group demonstrated statistically significantly more improvement than the control group (R-THROAT score improved by 1.97 in the intervention group vs 0.87 in the control;  $P = .04$ ). Two categories, tongue and mouth comfort, demonstrated the most significant improvement. However, there was no statistically significant difference in MSSA/MRSA colonization between the groups at the conclusion of the study (MSSA: 9.4% control vs 4.2% intervention;  $P = .45$ ; MRSA: 9.4% control vs 4.2% intervention;  $P = .45$ ). Overall, subjects in the intervention group were more satisfied with their protocol than subjects in the control group. Those in the intervention group also reported less drowsiness on day 4 ( $P \leq .05$ ). The limitation of this study was the investigation of just one pathogen, *S aureus*, and that the sample size was inadequate to detect differences in MSSA or MRSA acquisition or clearance. Nevertheless, this study offers an important evaluation of an oral care protocol after extubation. The results, specifically R-THROAT scores, demonstrate improvement in the oral cavity with the designed oral care intervention protocol.

**Chipps EM, Carr M, Kearney R, MacDermott J, et al.** *Worldviews Evid Based Nurs* 2016;13:102–111. **References:** 29. **Reprints:** Dr Esther M. Chipps, Wexner Medical Center, The Ohio State University, 600 Ackerman Rd, E2019, Columbus, OH 43209, USA. Email: Esther.chipps@osumc.edu  
—Loke Weiqiang, Singapore

# One- and Two-Piece Implants Placed in the Same Patients: Clinical Outcomes After 5 Years of Function

Zeev Ormianer, DMD<sup>1</sup>/Mariusz Duda, DMD<sup>2</sup>/Jonathan Block, DMD<sup>3</sup>/Shlomo Matalon, DMD<sup>4</sup>

A retrospective evaluation of 24 subjects treated with one-piece (1P) ( $n = 34$ ) and two-piece (2P) ( $n = 38$ ) implants placed in contralateral mandibular premolar locations was conducted. Cumulative implant survival was 100% following a 5-year (range = 59.9–72.3 months; mean = 63.1 months) postrestoration monitoring period. Bone loss ( $P = .1952$ ) and prosthetic complications ( $P = .3667$ ) did not significantly differ between the two groups. Clinical efficacy was equivalent for both implant designs. *Int J Prosthodont* 2016;29:608–610. doi: 10.11607/jp.4786

Long-term clinical documentation of two-piece (2P) implants is readily available, but similar data on one-piece (1P) implants is limited. Since implant and abutment sections are manufactured as a single unit, loading of 1P implants after placement can be difficult to control.<sup>1</sup> In contrast, 2P implants undergo submerged healing, transmucosally with a healing collar, or after immediate loading if primary stability is judged as adequate.<sup>2</sup> The question of how to manage 1P implants that lack adequate primary stability for immediate loading remains unanswered. Comparative long-term clinical data on both 1P and 2P implant designs would benefit from evidence-based treatment planning.

This retrospective study compared long-term survival, marginal bone loss, and prosthetic complications of 1P and 2P implants placed contralaterally in the mandibles of the same patients.

## Materials and Methods

Dental implant patients who requested immediate esthetic restorations in the lead author's private practice were treated with 1P implants if at least 30

Ncm of implant insertion torque<sup>3</sup> could be achieved. Implants with lower torque values were immediately removed and replaced with a 2P implant. A retrospective review of patient records was conducted by trained and qualified dental students under the supervision of an experienced university researcher who standardized the measurement techniques. All patients were informed of the nature of the clinical decision and its rationale, as well as the intention to record clinical outcomes for documentation and publication purposes. Records of all patients who presented for treatment of one or more missing and/or unsalvageable mandibular premolar teeth bilaterally were identified, and this group was sorted to only include patients treated with both 1P (Zimmer One-Piece, Zimmer Biomet) and 2P (Tapered Screw-Vent, Zimmer Biomet) implants with tapered abutments (Hex-Lock Contour Abutments, Zimmer Biomet) (Fig 1). These implants shared identical macrostructures, lengths, diameters, and surfaces, and primarily differed in the presence (2P) or absence (1P) of an implant-abutment prosthetic connection. Criteria for study inclusion are summarized in Table 1.

Clinical data was recorded on spreadsheets in a password-protected database. Distribution of treatment by implant type (1P or 2P), mandibular quadrant (left or right), and premolar location (first or second) was arbitrary and based on individual patient needs. Study endpoints were implant survival, marginal bone changes, and prosthetic complications. Since radiographs were standardized (Rinn XCP, Dentsply), the student investigators were specially trained to evaluate mesial and distal crestal bone loss in incremental ranges of 0 to 1 mm, 1 to 2 mm, and 2 mm or more by measuring the distance from the radiographically visible implant-abutment junction on 2P implants or the crown-abutment connection on 1P implants to the highest point of bone contact with the implant surface using digital optical software. Differences in bone contact points were recorded as bone loss or bone

<sup>1</sup>Senior Lecturer, Department of Oral Rehabilitation, Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel.

<sup>2</sup>Private Practice, Clinic of Oral Implantology Silesia-Med, Katowice, Poland.

<sup>3</sup>Clinical Instructor, Department of Oral Rehabilitation, Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel.

<sup>4</sup>Senior Lecturer, Department of Oral Rehabilitation, Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University, Tel Aviv, Israel.

**Correspondence to:** Dr Zeev Ormianer, Department of Oral Rehabilitation, School of Dental Medicine, Tel Aviv University, Ramat Aviv, Tel Aviv 69978, Israel. Fax: +972 (03)-6124226.  
Email: ormianer@post.tau.ac.il

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**Fig 1** The 1P (*left*) and 2P (*right*) implants placed in the study. Note the implant-abutment interfacial crevice of the 2P implant.

**Table 3** 1P and 2P Implant Length and Diameter Distribution

Variable	1P (n [%])	2P (n [%])
Bone graft		
No	31 (81.6)	6 (17.6)
Yes	7 (18.4)	28 (82.4)
Implant diameter (mm)		
3.0	0 (0)	9 (26.5)
3.7	35 (92.1)	23 (67.6)
4.7	3 (7.9)	2 (5.9)
Implant length (mm)		
10.0	15 (39.5)	17 (50.0)
11.5	18 (47.4)	16 (47.0)
13.0	5 (13.1)	3 (3.0)

Bone grafting of gaps between the implant and the walls of a fresh extraction socket was performed in immediate placement cases.

gain. Fisher Exact test was used for all comparisons, and no adjustments were made for multiplicity.

## Results

Data were collected from 14 men and 10 women ranging in age from 25 to 60 years (mean = 46.9 years) (Table 2). A total of 17 patients were treated with multiple 1P ( $n = 2$ ) and 2P ( $n = 2$ ) implants, 7 subjects received multiple 2P ( $n = 2$ ) and single 1P implants, and single 1P and 2P implants were placed in all other patients (Table 3). Implants were monitored for at least 5 years (range = 59.9–72.3; mean = 63.1 months) postrestoration.

Cumulative 1P and 2P implant survival was 100% with no significant differences in bone loss (Fisher Exact;  $P = .1952$ ) (Table 4) or prosthetic complications (Fisher Exact;  $P = .3667$ ), which were limited to 12 porcelain fractures (2P = 8; 1P = 4).

**Table 1** Study Inclusion and Exclusion Criteria

### Inclusion

- 1P and 2P implants from the same manufacturer
- Both 1P and 2P implants placed contralaterally in mandibular premolar locations of the same patients
- 1P and 2P implants placed within 3 months of each other
- At least 30 Ncm of insertion torque for placement of 1P implants
- Less than 30 Ncm of insertion torque for placement of 2P implants
- At least 60 months of clinical follow-up after restoration

### Exclusion

- Failure to meet any of the inclusion criteria

**Table 2** Age and Sex Distribution of the Selected Patients

Variable	Summary statistics	
Sex		
Men		10 (41.7%)
Women		14 (48.3%)
Mean age (y)		46.9

**Table 4** Statistical Analysis of Implant Survival, Graduated Bone Loss, and Prosthetic Complications

Variable	1P (n [%])	2P (n [%])	Statistical test	P
Bone loss (mm)				
0.0	29 (85.3)	33 (86.8)	Fisher Exact	.1952
1.0	3 (8.8)	4 (10.5)		
2.0	1 (5.6)	1 (2.8)		
Implant survival	34 (100)	38 (100)	NA	NA
Yes				
Prosthetic complications				
No	30 (88.2)	30 (78.9)	Fisher Exact	.3667
Yes	4 (11.8)	8 (21.1)		
Follow-up (mo)	60 (range = 59.9–72.3; mean = 63.1)			

## Discussion

After 5 years of postrestoration follow-up, there were no significant differences between 1P and 2P implants placed in the same patients and exposed to the same clinical conditions. The primary design difference between the implants was the presence or absence of an implant-abutment prosthetic connection, which may have affected early bone loss and prosthetic complications.<sup>4</sup> Larger randomized clinical trials are needed to robustly assess long-term outcomes of the different protocol choices described in this article. However, this preliminary report did not reveal any differences.

## Conclusions

Within the limitations of this study's time frame, 1P and 2P implants appeared to be equally effective after 5 years of function in the same patients.

## Acknowledgments

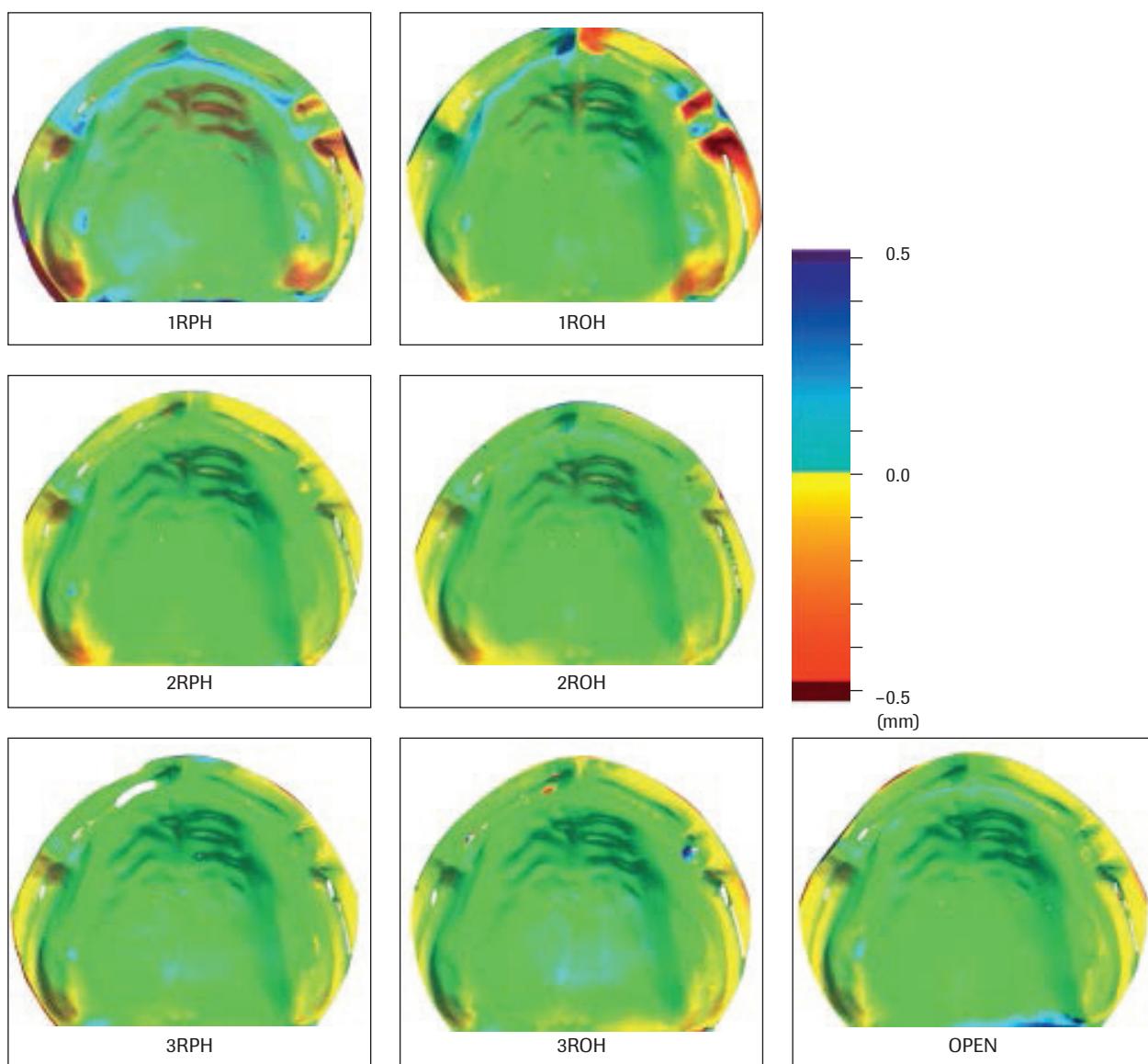
The authors reported no conflicts of interest related to this study.

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## Erratum

In the article by Shin et al (The Effect of Edentulous Maxillary Impression Tray Designs When Flabby Tissue Is Present: An In Vitro Study), in Volume 29, Number 5 (September/October), 2016, the color scale for Fig 3 (page 470) was printed incorrectly. The corrected figure is presented here.



**Fig 3** 3D color map displaying the distance between the test and the control model. The flabby tissue regions of one-baseplate wax relief groups (1RPH, 1ROH) display a large amount of displacement. 1ROH = one-wax relief and overall escape hole; 1RPH = one-wax relief and palatal escape hole; 2ROH = two-wax relief and overall escape hole; 2RPH = two-wax relief and palatal escape hole; 3ROH = three-wax relief and overall escape hole; 3RPH = three-wax relief and palatal escape hole.

# Implant Ball Attachment Fabricated with CAD/CAM to Overcome an Unfavorable Clinical Situation: A Case Report

Ji Suk Shim, DDS, MSD<sup>1</sup>/Jae Hyung Lim<sup>1</sup>/Jung Hyun Shin, DDS<sup>2</sup>/Jae Jun Ryu, DDS, PhD<sup>3</sup>/Jeong Yol Lee, DDS, PhD<sup>4</sup>/Sang Wan Shin, DDS, PhD<sup>4</sup>

The most common complication of implant ball attachments is loss of retention via structural wear. Hence, parallel placement of implants was identified as a prerequisite for long-term success. In this case, although severe angulation was formed between implants due to severe alveolar bone resorption, parallel ball attachments on the implants could be fabricated using computer-aided design/computer-assisted manufacture. This procedure can be a solution when implants are placed with angulation and offers additional advantages such as long-term stability. *Int J Prosthodont* 2016;29:611–613. doi: 10.11607/jp.4914

Implants with attachments are a solution for removable denture cases that cannot function appropriately because of the limitations of the underlying oral anatomy. For example, some authors have recommended the restoration of severely resorbed edentulous mandible with an overdenture retained by implant attachments.<sup>1,2</sup>

Angulation can lead to poor adaptation of the attachment or loss of retention. For the success and long-term stability of treatment with attachments on implants, the implants should be placed parallel.<sup>3</sup> Because of the technical limitations of clinicians, the anatomy of the alveolar bone, and the general condition of the patient, however, the parallel path between implants cannot be secured in every case.

The present study reports the fabrication of implant ball attachments with a computer-aided design/computer-assisted manufacturing (CAD/CAM) system to overcome the unfavorable clinical situations of severely angled implants.

## Case Report

A 72-year-old woman presented to the dental clinic at Korea University Ansan Hospital with repeated

swelling, pain, and fistula after the extraction of a mandibular anterior tooth. Based on the patient's symptoms and medical history of bisphosphonate treatment, she was diagnosed with medication-related osteonecrosis of the jaw (MRONJ) and was treated first with conservative approaches including antibacterial mouthrinse and antibiotic medications. Despite the treatments, the symptoms worsened; hence, the infected tissues were surgically resected.

Although the symptoms subsided after the surgical intervention, the patient showed massive loss of alveolar bone and lost several teeth (Fig 1). Because the cantilever was large and the conventional removable partial denture (RPD) could exert excessive force on the remaining teeth, implants were placed to support the RPD on the edentulous area. Considering the age and medical history of the patient, the implants were placed vertically on the ridge without bone graft after minimal incision (Fig 2).

Impressions were taken for each implant separately 2 months after the surgery. The master casts were scanned using a model scanner, and the abutments were designed in a CAD program (Dental CAD, exocad). The path of ball attachment was determined by considering the angle of guiding surface of abutments on both sides (Fig 3). To harmonize the paths between the attachments, the second and third abutments were designed in reference to the previously fabricated abutment after overlapping the models in the CAD program. Each ball attachment was fabricated with a milling machine.

The fabricated abutments were delivered to the patient, and final impressions were taken for RPD. The RPD retention was considered sufficient because of the three ball attachments on the implants and the clasps of the RPD located along the height of contour, bracing and guiding the path of insertion without retentive effect (Fig 4).

<sup>1</sup>Professor, Korea University Ansan Hospital, Gyeonggi-do, Republic of Korea.

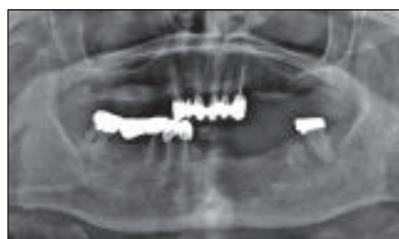
<sup>2</sup>Professor, Dankook University Jukjeon Dental Hospital, Gyeonggi-do, Republic of Korea.

<sup>3</sup>Professor, Korea University Anam Hospital, Seoul, Republic of Korea.

<sup>4</sup>Professor, Korea University Guro Hospital, Seoul, Republic of Korea.

**Correspondence to:** Dr Sang-Wan Shin, Department of Advanced Prosthodontics, Korea University Guro Hospital, #148, Gurodong-ro, Guro-gu, Seoul 152-703, Korea. Fax: 82-2-866-1499.

Email: swshin@korea.ac.kr



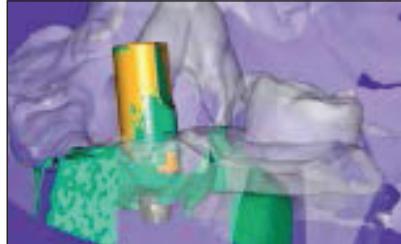
**Fig 1** After surgical intervention for removal of infected tissue, the symptoms subsided. However, a large amount of the bone and multiple teeth were also removed.



**Fig 2** Implants were placed vertical to the alveolar ridge without bone graft; however, they were severely angulated.



**Fig 3** The attachments were designed with a CAD program. The path of ball attachment was determined by considering the angle of guiding surface of the abutments on both sides. To harmonize the paths between the attachments, the second and third abutments were designed in reference to the previously fabricated abutment after overlapping the models in the CAD program.



The patient was followed up 1 day, 2 weeks, 3 months, and thereafter every 6 months after delivery of the prosthesis. The patient was satisfied with the prosthesis, and no specific complications were observed until 9 months after delivery. Although the maxillary prosthesis also seemed unfavorable, the patient did not feel any discomfort at the maxilla and wanted to delay the additional treatment until after the recovery of her general health. Therefore, radiographic and clinical evaluations were performed for both maxillary and mandibular prostheses during follow-up visits.

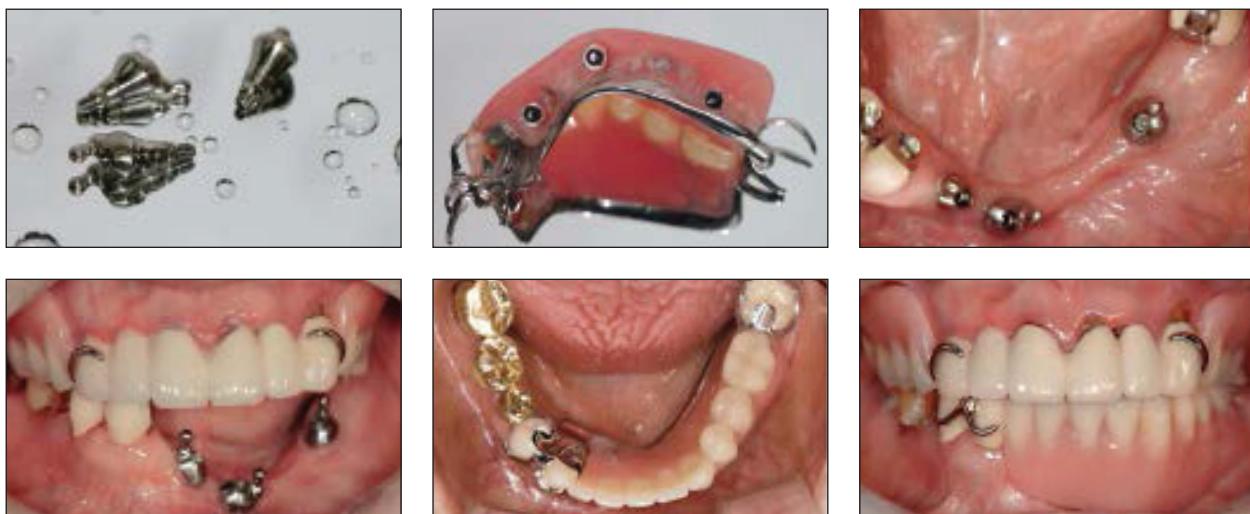
## Discussion

A ball attachment on an implant has the advantages of ease of maintenance for hygiene, low cost, and minimal chair time. The most common complication with

ball attachment is loss of retention by structural wear, and some authors have recommended the use of ball attachment only when the implants are placed parallel or angled < 15 degrees.<sup>4</sup>

The fabrication of the attachments with CAD/CAM allowed harmonization of the path between attachments, and the incidence of structural wear could be reduced even though the implants were severely angulated in relation to one another. Moreover, refabrication of the male part of the attachment is easy as long as the CAD images are kept, and the attachment can be changed when the ball is worn out.

A disadvantage of ball attachment is that it requires more vertical space.<sup>5</sup> Ball attachments with various vertical dimensions depending on the case can be fabricated with CAD/CAM, although improvement is needed in software and milling machines.



**Fig 4** The attachments were fabricated with a milling machine and installed on the implants. After delivery of the overdenture, the patient was satisfied with the prosthesis function.

## Conclusions

CAD/CAM fabrication of implant ball attachments can be a solution when implants are placed with angulation. This technique offers advantages such as maintenance for long-term stability.

## Acknowledgments

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### Literature Abstract

#### Bone Augmentation at Implant Dehiscences and Fenestrations: A Systematic Review of Randomized Controlled Trials

The article aimed to verify and compare the efficacy of horizontal bone augmentation techniques in one-stage implant procedures. A total of 15 randomized controlled trials satisfied the search criteria and were included in the study. Different types of augmentation procedure, membrane, and graft were compared. Statistically significant differences were found for vertical variation of the peri-implant defect favoring the use of membranes. Of the membranes tested, ePTFE were favored over PLGA. No significant differences were found between other membranes. There were significant differences favoring the use of rhBMP-2 in addition to bovine inorganic bone as compared with Bio-Oss alone. The combination of Ceros TCP (pure beta-tricalcium phosphate bone graft) and Jason (porcine pericardium collagen membrane) showed significantly better results radiographically than Bio-Oss and BioGide. The authors concluded that the use of a membrane could contribute to the regeneration of the hard tissue. No differences were observed comparing nonresorbable ePTFE membranes and resorbable collagen membranes. No substantial differences were obtained using different nonresorbable membranes and grafts. The article also mentioned there was high risk of bias in most included studies.

**Merli M, Merli I, Raffaelli E, Pagliaro U, Nastri L, Nieri M.** *Eur J Oral Implantol* 2016;9:11–32. **References:** 85. **Reprints:** Mauro Merli, Viale Settembrini 17, 47923 Rimini, Italy. Fax: +39-0541-52308. Email: mauromerli@gmail.com —Huong Nguyen, USA

# Esthetic Restoration of Multiple Congenitally Missing Anterior Teeth with Oral Implants: A Clinical Case Report

Jiawei Wang, DDS, PhD<sup>1</sup>/Fangjun Teng, DDS<sup>2</sup>/Hong He, DDS, PhD<sup>3</sup>/Huifen Ding, DDS, PhD<sup>4</sup>/Yong Li, MS<sup>5</sup>

Having multiple congenitally missing anterior teeth heavily influences the patient's countenance and pronunciation. There are few reports on the esthetic restoration of such situations with oral implants. This clinical case history report presents a multidisciplinary approach to treat a young woman with multiple congenitally missing anterior teeth using implant-supported prostheses. The treatment steps and clinical implications are discussed. *Int J Prosthodont* 2016;29:614–617. doi: 10.11607/ijp.4901

**H**aving congenitally missing anterior teeth heavily influences the patient's countenance and pronunciation. In particular, the prevalence of dental agenesis in women is 1.37 times higher than that in men. Patients with congenitally missing anterior teeth usually suffer from deviated upper and lower midlines, abnormal overlap and overbite, retention of deciduous teeth, reduction of lower facial height, reduced chewing ability, and other functional problems.<sup>1</sup>

Orthodontic treatment such as mesially moving posterior teeth to close the space may be used for patients with few missing anterior teeth. However, the indication is limited.<sup>2</sup> On the other hand, prosthodontic treatment alone does not guarantee sufficient esthetic results either. Esthetic restoration of anterior hypodontia should take a multidisciplinary approach, which combines the benefits of orthodontic, periodontic, and prosthodontic treatments.<sup>2,3</sup>

In recent years, successful implant restoration of patients with individual congenitally missing anterior

tooth has been reported. However, there are few reports on implant restorations for multiple missing anterior teeth, which have more challenging and less predictable esthetic and functional outcomes.

## Case History Report

A 21-year-old woman was referred to the department with the chief complaint of congenitally missing teeth. Intraoral examination revealed an Angle class I malocclusion, many missing teeth and sporadic diastemas, normal overbite and overjet, and acceptable periodontal condition. The clinical crown lengths of the maxillary central incisors were short, and there were no signs or symptoms of temporomandibular joint dysfunction (Figs 1a to 1c).

Orthodontic treatment was planned as the first step to close the sporadic diastemas and create adequate restoration space. After 2 years (Figs 1d to 1f), the patient was given different treatment options. She selected implant-supported dentures to rehabilitate the missing teeth and accepted a crown-lengthening surgery to acquire esthetic width-to-length ratio of the maxillary anterior teeth. The result of cone beam computed tomography revealed that the alveolar buccolingual widths were 4 mm in the maxillary right canine and 3 mm in the maxillary left canine and mandibular lateral incisors. All implant placement sites had adequate vertical bone mass (Figs 1g to 1j).

During the initial surgical phase, the maxillary deciduous canines were extracted and the crown lengths of the maxillary central incisors were extended to ideal size through removal of part of the mucoperiosteum and alveolar bone. The alveolar ridge at maxillary right canine and left lateral incisor and canine was trimmed into a natural scalloped edge. Implants (TS 3.5 × 10 mm, Osstem) were immediately placed at the maxillary canines, and a labial guided bone regeneration procedure was performed (Figs 2a to 2d).

<sup>1</sup>Professor, Department of Prosthodontics, Hubei-MOST KLOS & KLOBM, School and Hospital of Stomatology, Wuhan University, Wuhan, China.

<sup>2</sup>MSD Student, Department of Prosthodontics, Hubei-MOST KLOS & KLOBM, School and Hospital of Stomatology, Wuhan University, Wuhan, China.

<sup>3</sup>Professor, Department of Orthodontics, Hubei-MOST KLOS & KLOBM, School and Hospital of Stomatology, Wuhan University, Wuhan, China.

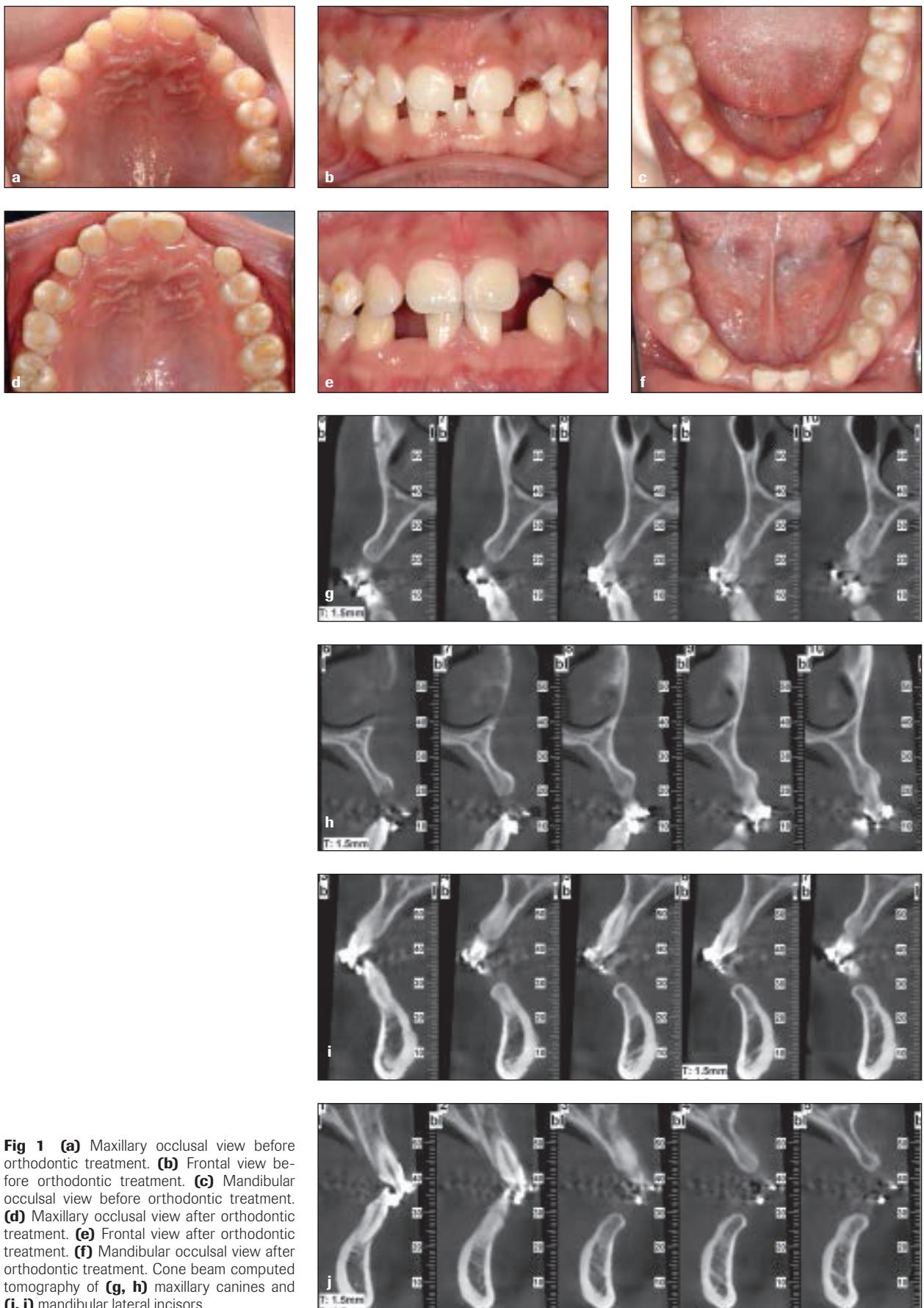
<sup>4</sup>Researcher, Hubei-MOST KLOS & KLOBM, School and Hospital of Stomatology, Wuhan University, Wuhan, China.

<sup>5</sup>Registered Dental Technician, Department of Prosthodontics, Hubei-MOST KLOS & KLOBM, School and Hospital of Stomatology, Wuhan University, Wuhan, China.

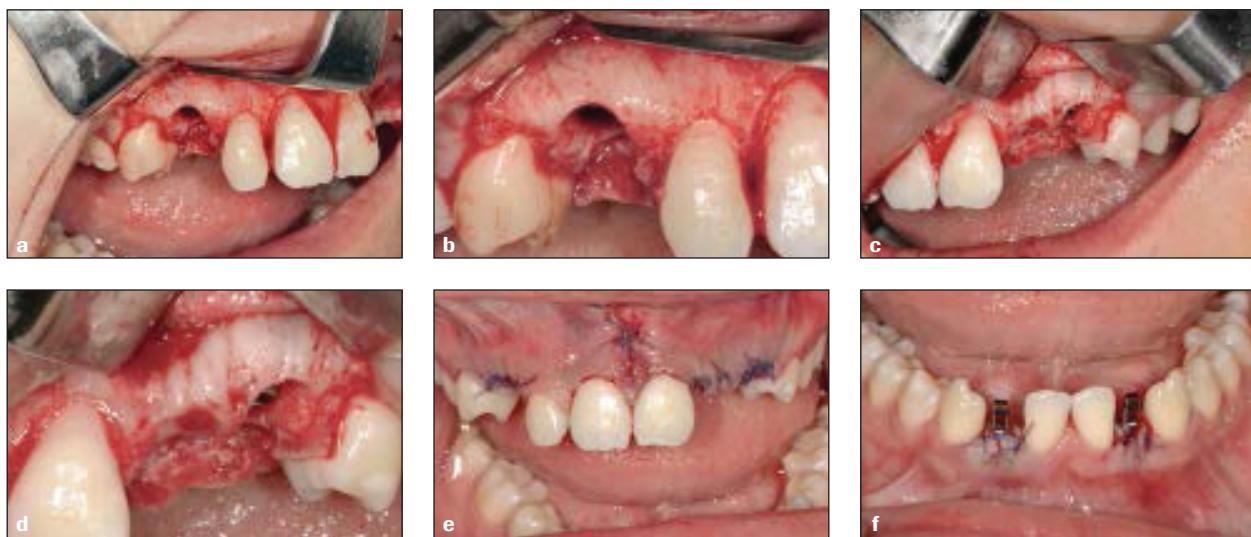
**Correspondence to:** Dr Jiawei Wang, Department of Prosthodontics, School and Hospital of Stomatology, Wuhan University, 237 Luoyu Road, Wuhan, 430079, PR China. Fax: 0086 (0)2787873260.

Email: wangwei@hotmail.com

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**Fig 1** **(a)** Maxillary occlusal view before orthodontic treatment. **(b)** Frontal view before orthodontic treatment. **(c)** Mandibular occlusal view before orthodontic treatment. **(d)** Maxillary occlusal view after orthodontic treatment. **(e)** Frontal view after orthodontic treatment. **(f)** Mandibular occlusal view after orthodontic treatment. Cone beam computed tomography of **(g, h)** maxillary canines and **(i, j)** mandibular lateral incisors.



**Fig 2** Implant placement. **(a, b)** The crowns of the maxillary central incisors were lengthened and an implant was immediately placed in the maxillary right canine site. **(c, d)** The same operation was performed in the left maxilla and the wound was carefully sutured. **(e)** Postoperative view of the maxilla. **(f)** Postoperative view of the mandible.



**Fig 3** **(a)** Provisional teeth were fixed 1 month after the surgery. **(b)** Satisfactory gingival papillae height and fullness were obtained after 5 months. **(c)** The impression was taken using provisional teeth as the impression post. **(d)** The zirconia abutments, crowns, and cantilever bridge.

Two small-diameter implants (MS 2.5 × 10 mm, Osstem) were placed in the mandibular lateral incisors. The wound was carefully stitched and the suture was removed after 2 weeks (Figs 2e and 2f).

Provisional teeth were fixed after 1 month for gingivoplasty. The gingival papillae at the maxillary lateral incisors and canines had achieved sufficient height and fullness after 5 months (Figs 3a and 3b). The final impressions were taken using provisional teeth as the impression post to record the gingival profile (Fig 3c). Zirconia abutments, crowns, and cantilever bridge were prepared (Fig 3d). A satisfactory esthetic result was achieved (Figs 4a to 4f). The postoperative panoramic radiograph showed good osseointegration

with no obvious bone resorption around the implants (Fig 4g). The patient was followed up for 18 months without any abnormal soft tissue reaction.

## Discussion

Similar to most tooth extraction patients, anterior hypodontia patients have a deficient osseous ridge in the labial aspect of the edentulous area and excessive bone in the vertical direction. Consequently, in this case the alveolar crest was trimmed into a scalloped edge according to the location and contour of the alveolar ridge of adjacent teeth.<sup>4</sup> In addition, due to the lack of stimulation from the tooth root and the



**Fig 4** (a) Intraoral right lateral view after treatment. (b) Intraoral frontal view after treatment. (c) Intraoral left lateral view after treatment. (d, e, f) Confident smile and esthetic appearance. (g) Panoramic radiograph after prostheses placement.

retention of deciduous teeth, the restoration space after orthodontic movement is generally inadequate. Therefore, small-diameter implants were proposed.<sup>5</sup> Finally, because of incomplete tooth eruption or orthodontic intrusion seen in anterior hypodontia patients, the gingival curve of natural teeth needed to be adjusted to obtain an ideal width-to-length ratio. However, the esthetic outcome at the site of consecutively missing anterior teeth was still compromised. Potential mechanical risks of the single implant-supported cantilever denture should be followed up.

## Conclusions

A young woman with multiple congenitally missing anterior teeth was restored with implant-supported zirconia crowns and a cantilevered bridge leading to satisfactory esthetics and function. However, long-term follow-up evaluation is needed and more case histories should be observed to evaluate the treatment option.

## Acknowledgments

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THE OHIO STATE UNIVERSITY

Columbus, Ohio

## Maxillofacial Prosthodontist

The Ohio State University College of Dentistry  
Arthur G. James Cancer Hospital and Richard J. Solove Research Institute

The Ohio State University College of Dentistry seeks a maxillofacial prosthodontist for a full time, clinical-track position as an Associate Professor, or as a tenured Associate Professor, in the Division of Restorative, Prosthetic and Primary Care Dentistry, with a joint appointment at The Ohio State University Comprehensive Cancer Center and the Arthur G. James Cancer Hospital and Richard J. Solove Research Institute. For a tenured appointment, candidates must demonstrate a sustained, outstanding record in teaching and research.

The Ohio State University College of Dentistry is the only public dental school in Ohio. The college is composed of nine divisions or academic units. All major ADA-recognized clinical dental specialties are represented. The primary

academic responsibilities for this faculty position will be contributing to the didactic and clinical instruction in the pre-doctoral program and the graduate program in Advanced Prosthodontics. Other responsibilities will include prosthodontic care of patients with acquired and congenital maxillofacial defects and support of surgical and related oncologic departments.

The Ohio State University Comprehensive Cancer Center is dedicated to the creation of knowledge in laboratory, clinical and population-based cancer research. The Center applies those discoveries to develop more effective approaches to cancer prevention, diagnosis and therapies — providing tomorrow's standard of care today.

Applicants must have a D.D.S./D.M.D. degree or equivalent and a certificate of advanced

education in maxillofacial prosthodontics from a CODA-accredited program, must be board-certified, and eligible for licensure by the Ohio State Board of Dentistry. Preference is given to those with significant clinical experience and prior experience in dental education. Other duties include contributing to the overall mission of the Division of Restorative, Prosthetic and Primary Care Dentistry, and participating in the college's faculty practice and continuing education program.

Evaluation of applications will begin immediately and will continue until the position is filled. Salary and academic rank are commensurate with qualifications. Applicants should provide a personal statement delineating qualifications and career goals, a curriculum vitae, and three letters of recommendation.

**Application materials or inquiries should be sent electronically to Emily Lyles, Assistant to the Dean, at [lyles.40@osu.edu](mailto:lyles.40@osu.edu).  
For more information about the college, the division and this position, visit [www.dent.osu.edu](http://www.dent.osu.edu).**

The College of Dentistry's atmosphere is one of collaboration and inclusiveness, where differences in thought and experience are embraced and celebrated. The Ohio State University is an equal opportunity employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation or gender identity, national origin, disability status, or protected veteran status.





