Original Article

INFLUENCE OF CHEWING LOAD ON WEAR RATE OF POLYMETHYL METHACRYLATE DOUBLE CROSS-LINKED DENTURE TEETH IN VITRO

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ABSTRACT **DOI: 10.25241/stomaeduj.2018.5(4).art.1**

Purpose of the Study: Compare occlusal wear of PMMA DCL denture teeth under two different loads in vitro.
Materials & Methods: Sixteen mandibular second premolars (SR Orthoplane DCL) with a flat occlusal surface (specimens) were worn by sixteen maxillary second premolar-antagonists (Ortholingual DCL). These teeth were subjected in a chewing simulator (CS-4, SD Mechatronik) up to 240,000 loading cylces at 19.6N (LL ≈ full denture) and 68.6N (HL ≈ implant-overdenture) and TC (2,222 x 5 °C - 55 °C). Replicas of mandibular teeth were obtained at 0, 10,000; 20,000; 40,000; up to 240,000 cycles with polyvinyl-siloxane impressions and dental stone. Antagonist-replicas were made at baseline and at 240,000 cycles. The volumetric wear was determined with Geomagic after scanning replicas with a laser scanner. Linear regressions and ANOVA were used for statistical analysis.
Results: The wear rate of the HL-specimens was significantly higher than that of the LL-group ($p < 0.0001$). The LL-wear rate became linear after 60,000 cycles and was calculated to be 0.182×10^{-6} mm^3/stroke. The HL-wear rate was linear from 20,000 to 140,000 cycles and was 1.056×10^{-6} mm^3/stroke, then up to 240,000 cycles 0.656×10^{-6} mm^3/stroke. At 240,000 cycles the HL-group showed significantly higher antagonist-wear ($p < 0.0001$). The antagonists in both groups demonstrated higher wear than their opposing specimens ($p < 0.08$).
Conclusions: HL generated significantly higher wear of both the specimens and the antagonists. The antagonists showed higher wear than the specimens. As a clinical consequence one may expect more wear of denture teeth in implant supported overdentures than in full dentures.
Keywords: wear, denture, PMMA, cross linked, in vitro.

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1. Introduction

Estimates show that in the US the adult population in need of one or two complete dentures will increase from 35.4 million adults in the year 2000 to 37.9 million adults in 2020 [1]. Despite the fact that prevention is able to avoid tooth loss [2,3] these numbers are very high. There are basically two reasons for this. First, the population demographics have changed dramatically. Based on US census statistics, there are substantial trends observed for the time period 1991 – 2020. The total adult population will increase significantly from 187 million to 245 million; adults aged 55 to 74 years will increase by 86% from 39,280,000 to 73,099,000 and senior adults 75 years and older will increase by 61%, from 13,489,000 to 21,835,000 [4,5]. Second, the population older than 55 did not profit much from the benefits of prevention [1], and finally the social structure [6,7] combined with health care insurance being not mandatory has favored tooth extractions vs restorative dentistry. Thus, the aging population will bring with it an increase in the number of teeth lost [8]; projections for 2050 predict the number of edentulous people in the US at 8.6 million [6]. Life expectancy will continue to increase due to advances in the medical fields.

For over 100 years, complete maxillary and mandibular dentures have been the traditional standard of care for edentulous patients [9], in which patients still perceive improved treatment success in terms of increased prosthesis retention and stability in this treatment method [10]. However, many patients have limitations with stability and retention; over 50% of mandibular prostheses had such problems [11]. Edentulous patients have prosthodontic and physiologic limitations. With respect to physiology, significant amount of mechanoreception is compromised after teeth loss due to absence of the periodontal ligament, which contains sensory fibers. It leads to abnormal changes in magnitude, precision, and direction of occlusal load application [12]. Awad et al [13] reported that incorporating new dentures may result in improvements of overall satisfaction reported by patients, regarding aesthetics, comfort, and speech. On the other hand, for some patients, the incorporation of new dentures may not improve their function [13]. This confirms that there is a wide variety in the ability of edentulous patients to tolerate complete dentures [13,14]. Among elderly denture patients, 25 % experienced pain when chewing and 41 % needed more time for chewing. This can be explained with age related physiological changes, decreased motor control of the tongue, decreased biting force, and medication induced xerostomia [15]. People wearing full dentures have less than 20% of the masticatory performance of those with a natural dentition [16,17]. If a few teeth, preferably canines, are left and usable in the mandible, teeth supported overdentures can be incorporated, which means that complete dentures are supported by both edentulous ridges and the retained natural roots. This solution shows increased retention, stability, and comfort for the patients with increased quality of life [18]. With the introduction of titanium implants that osseointegrate in the 1970s [19-21] the way was open for implant supported overdentures with higher probability of success in the mandible when overdentures are supported by implants rather than tooth roots [22]. In the year 2002, the McGill consensus statement on overdentures declared that "Mandibular two-implant overdentures as first choice standard of care for edentulous patients [9] are based on an overwhelming evidence" [8]. This decision has been supported and the superiority of implant supported overdentures has been confirmed with systematic reviews [23,24].

Removable complete dentures consist of denture bases, which contain mostly polymethyl methacrylate [25]. Their designs are patient-specific, made during the prostheses processing in dental laboratories. Denture teeth are the other component of complete dentures, in general, there are three different materials used to fabricate teeth by dental manufacturers. The ceramic type was first introduced in Europe in 1789, its use is limited nowadays due to difficulty in adjustment and potential fracture from the denture base [26], although they have favorable esthetics and wear resistance. Acrylic resin denture teeth were introduced in the 1940s, and they contain mostly polymethyl methacrylate (PMMA). They are more frequently used than ceramic teeth in removable prosthodontics [27], due to some advantages such as excellent fracture toughness, easy occlusal adjustment and high bond strength to the denture base [28]. Their previous generations showed problematic wear resistance [29]. There are four subgroups under PMMA teeth; a) conventional unfilled, b) inorganically filled, c) highly cross-linked, and d) double cross-linked (DCL), which has improved mechanical and physical properties [30]. Composite resin denture teeth were introduced in the 1980s. It is claimed that they have more favorable esthetics and wear resistance [30].

Some studies showed an increase in motor control and perception in removable implant-retained prostheses [31]. In patients with complete dentures, a mean chewing force was reported in one study to be approximately 20 Newton [32], another study reported a mean chewing force of nearly 70 Newton in the mandibular implant-retained overdentures [33], indicating an overall increase of load on denture teeth within the studies' limitations.

Table 1. Ingredients of PMMA DCL denture teeth [60].

Ingredients	Weight %
Polymethyl methacrylate	33 - 35
Dimethylacrylate	5 - 7
Cross-linked PMMA	59
UDMA/PMMA fillers	0
Pigments	< 0.5
Initiators & stabilizers	< 0.5

Wear of acrylic resin teeth was reported in the literature. Wear is a phenomenon that occurs when two surfaces undergo a slipping movement under an applied load [34]. It is a complex, multifactorial process [35]. Abrasive wear occurs in natural and artificial teeth, it is the removal of material by the act of rubbing, cutting, or scraping [36]. Two-body abrasive wear occurs between denture teeth [37,38], which is friction between two surfaces without an abrasive agent or medium present. The attritional wear resistance of restorative materials limits the service time of the restorations [39].

Nowadays, many edentulous patients are treated using removable complete dentures with PMMA DCL denture teeth as a common choice, because of their better wear resistance [40]. In addition, there is an increased trend in patient acceptance of implant-retained overdentures. With a potential increase in motor control after implant treatment, it might be beneficial to know if the difference in chewing force will accelerate the wear of this type of popular artificial teeth. Therefore, the objective of this in vitro study was to compare the occlusal wear rate of the modern PMMA DCL denture teeth under two different loads. A low load simulated a mean chewing force in conventional complete dentures and a high load simulated a mean chewing force in implant-retained overdentures.

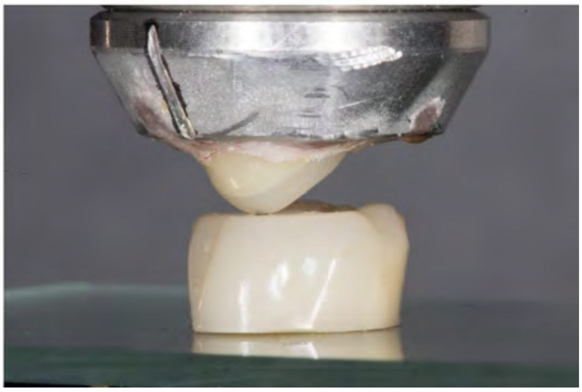
Null hypotheses:

- The in vitro wear of DCL PMMA denture teeth is independent of the chewing load;
- The in vitro wear of DCL PMMA denture teeth increases linearly with the number of chewing cycles.

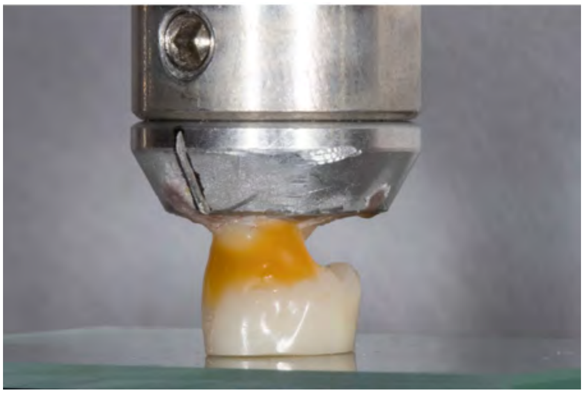
2. Materials and Methods

DCL PMMA denture teeth (Ivoclar Vivadent, Schaan, Liechtenstein) were selected. Sixteen mandibular second premolars (SR Orthoplane DCL ML6, REF 565849, LOT UP0794) were used as specimens and sixteen maxillary second premolars (Ortholingual DCL LU6, REF 565736, LOT UP2255) were used as antagonists. The composition of these denture teeth is shown on Table 1. These teeth were placed

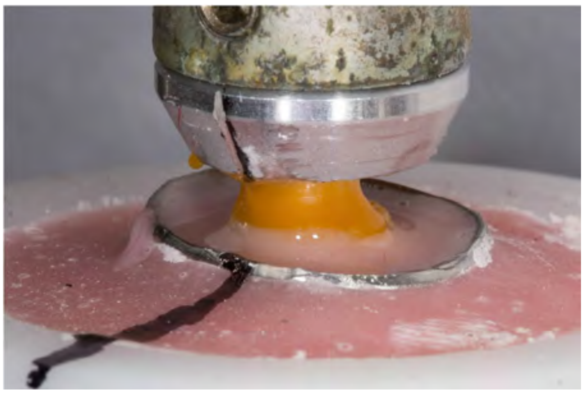
Figure 1. Use of a polyvinyl siloxane putty jig to achieve consistent relationship between the antagonist teeth to their holders. Note the mechanical retention on the antagonist holder to obtain a rotation lock.



(a) A mounted antagonist tooth with its palatal cusp in contact with the center of a flat occlusal surface on a specimen tooth.



(b) A specimen tooth was stabilized onto its antagonist tooth using a dental stick wax.



(c) Lowering the mouting jig arm to position specimen teeth into cold-curing acrylic resin.

Figure 2. Mounting of specimen teeth (a, b, c).

(a) Impression making of an antagonist tooth (left) and a specimen tooth (right).

(b) A stone replica of a specimen tooth.

(c) A stone replica of an antagonist tooth.

Figure 3. Impression making of specimens and antagonists (a, b, c).

in a chewing simulator (CS-4, SD Mechatronik, Feldkirchen-Westerham, Germany) at two different loads:

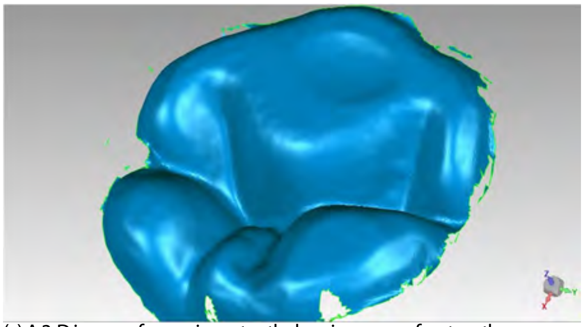
1. 19.6 Newton (low-load group): 8 specimens and 8 antagonists
2. 68.6 Newton (high-load group): 8 specimens and 8 antagonists

The maxillary premolars (antagonists) were mounted with cold-curing acrylic resin (Pro Base Cold, Ivoclar Vivadent) onto antagonist metal holders, modified with a rotary instrument to achieve extra retention, air-abraded with aluminum oxide particles and conditioned with Monobond Plus (Ivoclar Vivadent). A polyvinyl siloxane putty jig (Virtual® XD Putty, Ivoclar Vivadent, Amherst, NY) was made after mounting the first antagonist in order to get consistent relationship between the antagonist teeth to their holders (Fig. 1). The antagonists were slightly tipped to position their palatal cusps at the highest point to be in contact with the specimens, their buccal cusps were shortened to

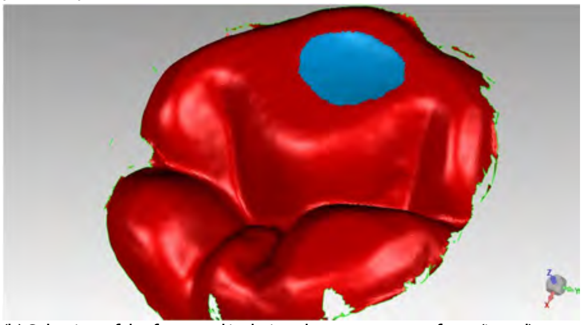
be in level with the embedding medium. A mounting jig system was used to conveniently achieve specific occlusal relationship between those prepared antagonists and their opposing specimens outside the chewing simulator machine. It was aimed to have each palatal cusp in contact with the center of the monoplane mandibular premolar's buccal cusp. Every mandibular premolar was stabilized using a small amount of dental sticky wax to a mounted antagonist in the defined position, and then the assembly was lowered into an individualized specimen holder, loaded with cold-curing acrylic resin for embedding (Fig. 2). These metal holders had irregular designs, in order to prevent positional errors. When the setting became fully completed, a polyvinyl siloxane putty jig was made to securely support the assembly's upper and lower components, which contained a pair of denture teeth, and then they were moved into the chewing simulator. The occlusal relationship in each pair of teeth was verified before having definitive positioning inside the machine.
The specimens were mounted randomly into the 8 chambers of the chewing simulator and stressed mechanically and thermally at 1.2 Hz with horizontal movement of 0.7 mm. Mechanical stresses were low-load (19.6 N) and high-load (68.6 N). Thermal stresses were introduced by cycling between 5 °C and 55 °C, dwell time was 30 s at each temperature with 15 s changing times for a total of 90 s per cycle. For 240,000 chewing strokes, there were 2,222 thermal cycles.
Impressions of mandibular teeth were obtained before starting the experiment and after 10,000; 20,000; 40,000; 60;000; 80,000; 100,000; 120,000, 140,000, 160,000, 180,000, 200,000, 220,000, and 240,000 chewing strokes using polyvinyl siloxane impression materials (Virtual® XD Extra-Light Body and Virtual® XD Heavy Body, Ivoclar Vivadent). Impressions of antagonist teeth were made at baseline and after the end of the experiment only. The following impression technique was used: one step heavy body/wash using small plastic containers (plastic bottle caps) as impressions trays (Fig. 3). The impressions were poured using type IV dental stone (Silky-Rock, Whip Mix, Louisville, U.S.) after being boxed (Fig. 3).

2.1. Quantification of wear

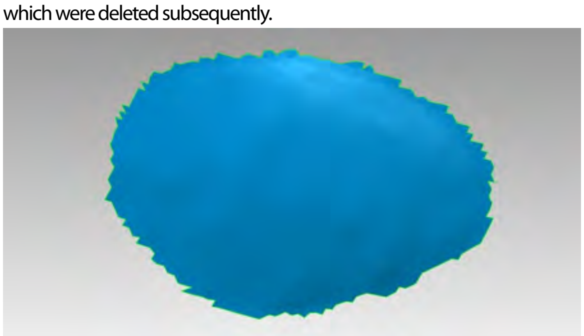
Stone models of both specimens and antagonists were scanned using a laser scanner (Laserscanner LAS-20, SD Mechatronik). The amount of wear was calculated using a 3-D software (Geomagic Control, 3Dsystems, Rock Hill, SC, USA). With respect to the specimens, the periphery of each worn area (facet) on the flat buccal cusp surface was selected first to be used as a reference. Then all the surrounding data (non-worn surfaces) were deleted, the depression inside the facet was filled using the "fill command", generating a flat surface coronally at the same level with the non-worn borders, the last step was to volumetrically measure the space within the worn area, which represented the amount material loss in cubic millimeter (Fig. 4). As for the antagonists, 3-D images of both the baseline and the final wear were superimposed using four reference points. Circular trimming was done for the superimposed models to



(a) A 3-D image of a specimen tooth showing a wear facet on the monoplane cusp.



(b) Selection of the facet and isolating the non-worn surfaces (in red), which were deleted subsequently.



(c) Close-up view: the facet area with its non-worn periphery after deleting the surrounding surfaces.

(d) Lateral view: the space within the facet was filled in creating a flat surface above in level with the non-worn periphery; it resembled the surface before starting wear simulation.

Figure 4. Quantification of wear in the specimen teeth (a-d).

delete all data that did not have any changes in the final wear image inferior to the worn cusp's borders. After isolating the superimposed worn and non-worn cusp tips the non-worn periphery was used as a reference to fill the space inside the cusp tip, volumetric measurements were taken in each model. The last step was to calculate the difference between them to yield in the material loss in cubic millimeter.

2.2. Evaluation of wear pattern

Surface details of the wear areas of both selected specimens and antagonists were inspected after completion of chewing rounds using digital microscopy (VH-1000 series, KEYENCE, Itasca, IL, U.S.) at 100x magnification, in order to evaluate the wear pattern.

2.3. Statistical analysis

Linear regression (SAS 9.4) of the amount of wear in volume against the number of chewing cycles was used to determine the wear rate of each specimen tested. The statistical difference between the mean wear rates of the two loading groups was determined by linear regression, ANOVA, and Tukey test. The statistical differences of the mean of total volume of wear of antagonists and the specimens as influenced by the loading were determined with the T-tests.

3. Results

The experimental data show that there is a linear relationship between the cumulative wear volume and the number of cycles ($R^2 > 95\%$ for all specimens), excluding the first reading of the high-load group and the first two readings of the low-load group (Fig. 5). In addition, the high-load group appears to have two segments with distinct linear relation intersecting at 140,000 cycles. ANOVA and Tukey test showed significant differences ($p < 0.0001$) between the two segments (68.6N-1 and 68.6N-2) of the high load group and between the high load group and the low load group (Fig. 5, Tab. 2). For the high load group two separate wear rates were calculated: from 20,000 to 140,000 cycles it was 1.056 x 10^{-6} mm^3/stroke, then up to 240,000 cycles 0.656 x 10^{-6} mm^3/stroke. The wear rate of the low load group was 0.182 x 10^{-6} mm^3/stroke (Tab. 2).

The wear of the antagonists at the end of the experiment (240.000 cycles) is shown in Fig. 6. As for the sample teeth, there is a significant difference between the high load and the low load group. Comparing the sample wear with the antagonist wear at 240.000 cycles T-tests revealed statistical differences ($p < 0.001$) between low-load group and either segment of high-load group, and between the two segments of the high-load group (Tab. 3).

The microscopic images showed comparable wear patterns among the two groups' specimens, unlike that of the antagonists, which showed coarse and irregular surface texture in the low-load group as compared to the high-load group (Figs. 7 & 8).

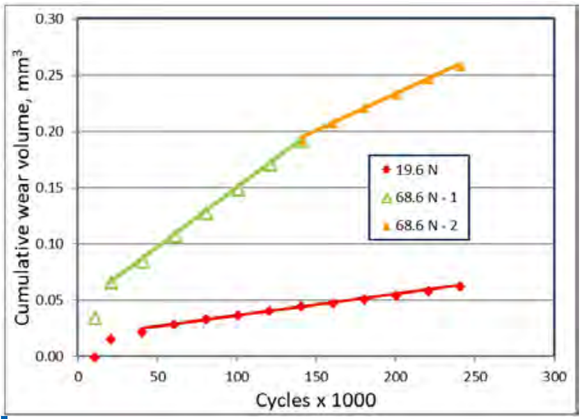


Figure 5. Mean wear volume as function of loading cycles. The high load group exhibits two segments (1 & 2) linear relationship and the straight line represents the best fit curve of the linear regression. ($p < 0.0001$).

Table 2. ANOVA and Tukey test for both segments of high load wear and the low load wear of the specimens. Dependent Variable: wear rate.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	3.05751734	1.52875867	116.84	<.0001
Error	21	0.27476608	0.01308410		
Corrected Total	23	3.33228342			
		R-Square	Coeff Var	Root MSE	CYCLE Mean
		0.917544	18.10987	0.114386	0.631621
Source	DF	Anova SS	Mean Square	F Value	Pr > F
LOAD	2	3.05751734	1.52875867	116.84	<.0001
Tukey Grouping	Mean	N	LOAD (N)		
A	1.05603	8	68.6		
B	0.65607	8	68.6		
C	0.18277	8	19.6		

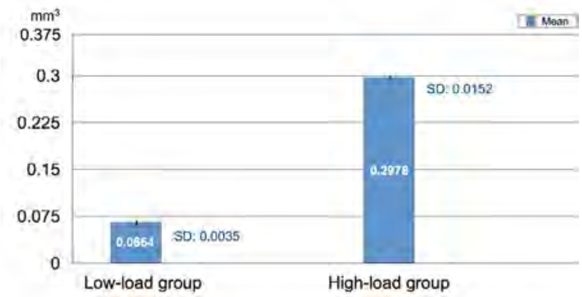


Figure 6. Wear of the antagonists in both groups (Mean ± SD), $p < 0.001$.

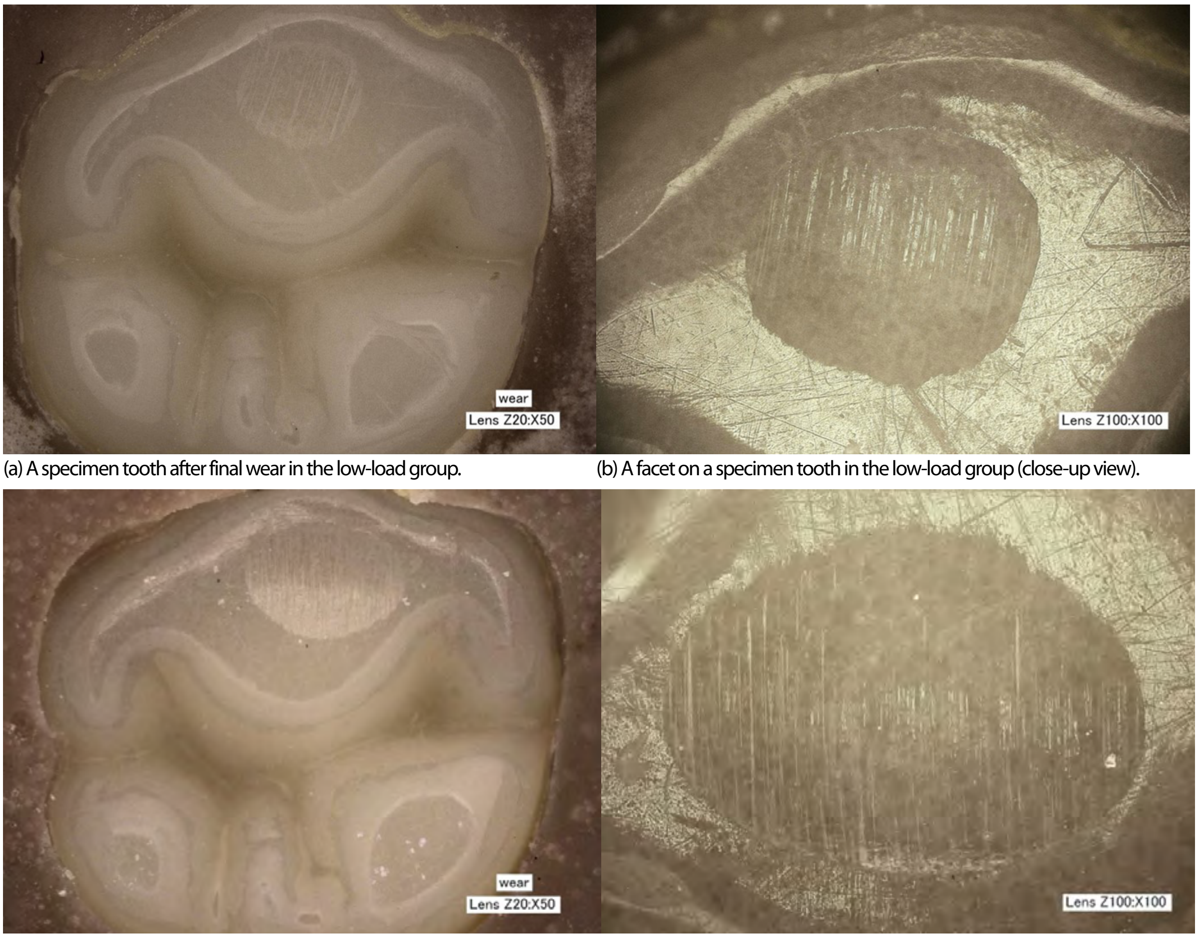
Table 3. Total wear volume (mean ± SD; in mm^3) at the end of the experiment. Different capital superscript letters show significant differences for columns and different low letters show significant differences for rows ($p < 0.001$).

Type of surface	Loading cycle	
	19.6 N	68.6 N
Antagonist	0.065 ± 0.004^{Aa}	0.298 ± 0.015^{Ab}
Specimen	0.063 ± 0.002^{Ba}	0.259 ± 0.090^{Bb}

4. Discussion

PMMA denture teeth have been used more frequently than other types due to favorable procedural and chemical properties [41]. Greater significance is added in studies when a commonly used material is selected for testing. The occlusal surface wear is a result of the combination of impact wear and sliding wear during process of mastication [42,43]. Progressive denture teeth wear results in insufficient posterior teeth support and consequently may lead to changes in the vertical and horizontal yaw relations and may cause functional and aesthetical impairments [44,45]. In order to assess the wear of a dental material such as denture teeth, it is advised to use impact and sliding as both occur on teeth surfaces during mastication. Denture teeth are used for edentulous patients, who have a reported mean chewing force of nearly 20 N wearing full dentures [32], and a mean chewing force of nearly 70 N with overdentures [33]. We assume that these values may reflect most clinical subjects, and can be used in chewing simulation studies.

A large number of chewing simulators have been used to determine in vitro wear of acrylic resin denture teeth [46-49]. In the present study the denture teeth were subjected to two-body wear, as it was reported in the literature [50-52]; it simulates the type of wear that occurs in full dentures with bilaterally balanced occlusion [51]. With respect to the selection of chewing cycles number, a wear simulation study



(a) A specimen tooth after final wear in the low-load group.

(b) A facet on a specimen tooth in the low-load group (close-up view).

(c) A specimen tooth after final wear in the high-load group.

(d) A facet on a specimen tooth in the high-load group (close-up view).

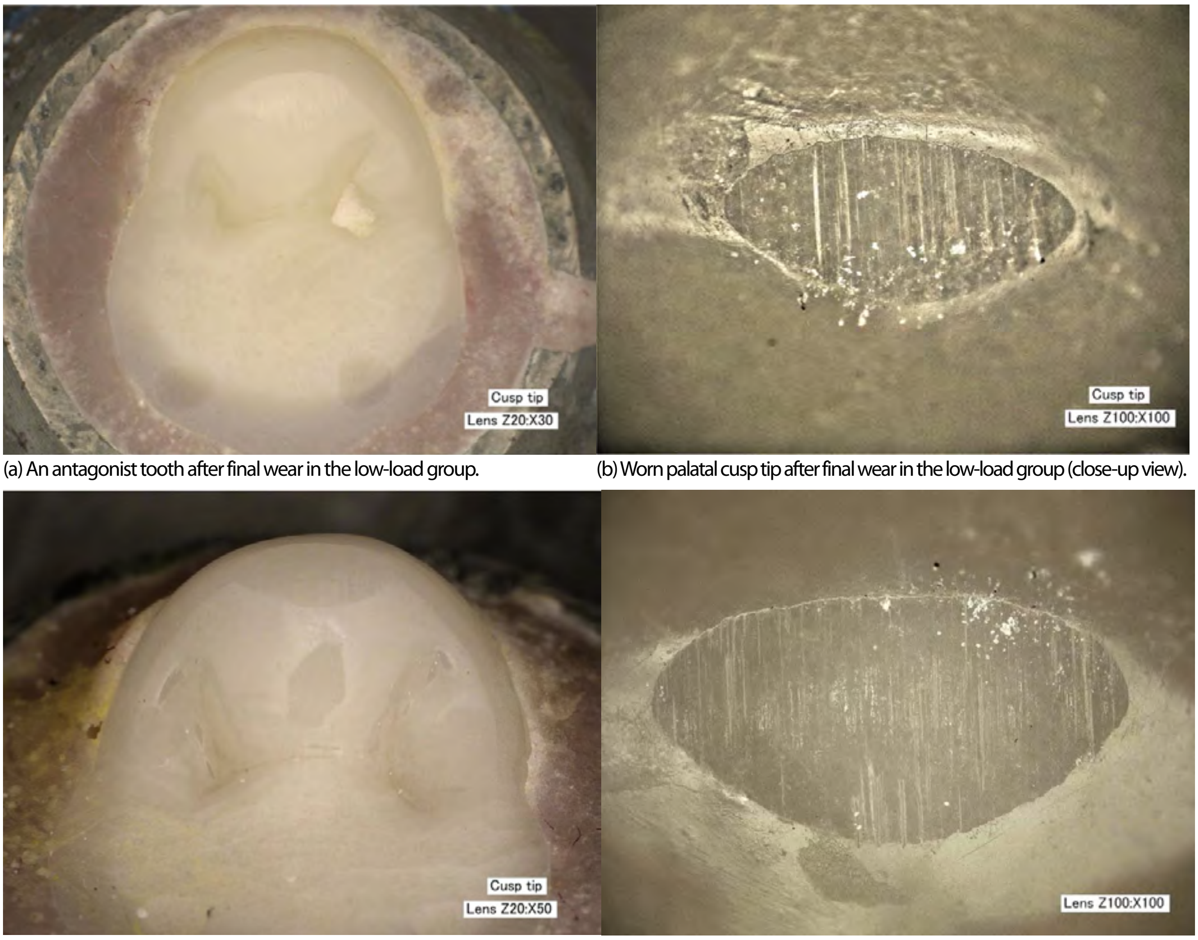
Figure 7. Microscopic digital images of specimen teeth in both groups a, b, c & d).

of IPN PMMA denture teeth had wear results after 200,000 chewing cycles [53] comparable to 1-year clinic follow-up results with the same material in two in vivo studies [54,55]. Thus, Coffey et al [53] assumed that the amount of wear occurring at 200,000 cycles would correspond to approximately 1 year of clinical function. Regarding the selection of fluid, distilled water was proved as a suitable intermediate medium, it did not have a significant difference with respect to mechanical properties of enamel and denture-base materials when compared to human saliva [56,57].

The selection of both specimens and antagonists denture teeth from the same material was done to simulate clinical conditions. The antagonist's material substantially influenced the wear rates in two-body wear [58]. In the present study, denture teeth with flat occlusal surfaces were used to simplify the wear analysis process. Measuring and interpreting the wear facet on a flat surface is more predictable than determining the wear on a complex occlusal surface with possibly more than one wear facet. Furthermore, it allowed comparisons with other studies using a similar approach [51]. When specimens with flat surfaces were exposed to antagonists from the same material, wear results were close to that of denture teeth's clinical wear [59]. Type IV low expansion dental stone replicas of denture teeth were produced after making polyvinyl siloxane impressions to investigate wear using a laser scanner, this method was considered accurate and reliable in other studies [59-61]. Furthermore, we had experienced distortions of the flat surface from wear facets scanned directly from ceramic discs [62]. The interpretation was that the laser beam, slightly entering a translucent surface was interacting with the material differently at an edge than on a regular surface. Therefore, for the present study the replica technique was preferred, where this phenomenon cannot happen with a stone surface.

The results of the present study showed significant differences in the wear rate between the low-load and the high-load groups for the specimens (Fig. 5) and the antagonists as well (Fig. 6). Mean wear rate of the high-load group specimens was 5.8 times greater before 140,000 cycles and 3.6 times greater after that turning point than the other group. As for their antagonists' mean wear rate, it was also greater by factor of 4.6. The linear regression analysis of the specimens wear rate showed an overall straight-line data in both groups, indicating approximately consistent relationship between number of cycles and amount of wear. No wear was detected in the low-load group until 10,000 chewing strokes, which might either show the lower limit of wear detection of this method or demonstrate favorable short-term wear resistance.

There are some possible explanations for the shift in the high-load group's specimens wear rate after



(a) An antagonist tooth after final wear in the low-load group.

(b) Worn palatal cusp tip after final wear in the low-load group (close-up view).

(c) An antagonist tooth after final wear in the high-load group.

(d) Worn palatal cusp tip after final wear in the low-load group (close-up view).

Figure 8. Microscopic digital images of antagonist teeth in both groups (a, b, c & d).

140,000 chewing strokes. Upon removal of fillers in the specimens due to the fatigue process of the filler/matrix during lateral movement, the antagonists became rough, causing accelerated wear [59]. The enamel layer's ingredients of the PMMA denture teeth might have different mechanical properties than that of dentin layer [25], it is possible that dentin layers of specimens and/or antagonists were exposed at around 140,000 strokes. The influence of the antagonist shape on wear rate of their opposing surfaces was reported, a ball-shape stylus generated significantly less wear on PMMA denture teeth than a conical ceramic stylus as it created less fatigue stress [59,63,64]. In the present study, more flattened antagonist's cusps appeared in the high-load group. We recommend using high-resolution microscopy to assess the ultrastructure of the specimens after each chewing round, which might help to detect possible differences in wear pattern. The difference may be due to the measuring technique as well. In the high load group some of the wear facets were extended slightly beyond the flat surface with the result that some of the volume was missing due to the fact that the flat surface was used as a reference.

The specimens' wear results were compared to previously reported data. One in vitro study showed significantly greater wear rate after 100,000 strokes [51] as compared to the low-load group in the present study, it might be caused by the abrasive nature of aluminum oxide antagonists and the greater chewing load they used (40 N) [51]. A 1-year clinical study showed a comparable result to the high-load group of the present study after 240,000 strokes, assuming the average number of annual chewing strokes is close to the suggested rate [65]. The results of the present study also support those from an in vitro study, which had steatite balls as antagonists, the researchers used 49 N chewing load [52], and their reported values were in between those of our low-load group and high-load group at both 120,000 and 240,000 strokes. Wear resistance is an important physical property of removable denture teeth [48,66]. Clinical problems were detected such as loss of vertical dimension, loss of masticatory efficiency, faulty teeth relationship that could affect patients and dental practice [11,44,67]. The previous generations of PMMA denture teeth had poor wear performance, as was detected in an in vitro three-body wear assessment for non-DCL PMMA teeth [29]. On the contrary, PMMA DCL denture teeth showed higher in vitro wear resistance than the conventional type [30,68]. With respect to the clinical wear assessment, patient-related factors should be considered, since there are differences among individuals in muscle activity, duration of dentures wear, presence or absence of para-functional habits and abrasiveness of food [65]. According to a clinical study, higher wear was detected in the implant-retained overdentures [33], this finding is in agreement with the present study, since the high-load group had greater wear.

There are only a few data about wear patterns of denture teeth. One in vitro study that had scanning electron microscopy (SEM) evaluation for PMMA DCL teeth opposed by the same tooth type using 30 N load after 100,000 cycles [59]. A direct comparison with these data is difficult, we used digital light microscopy vs SEM being used by Heintze et al 2012 [59]. In one group Heitze et al [59] used antagonists of the same material as the worn surface, however different diameters, different load (30 N) and 3 mm sliding distance vs 0.7 mm in the present study. The wear pattern of the DCL specimens in both studies seems to be comparable, showing uniformity with parallel fine grooves.

5. Conclusion

Modern PMMA DCL denture monoplane mandibular premolars were used as specimens opposed by semi-anatomic maxillary premolars as antagonists in a wear simulation experiment, with the chewing load as a variable factor.

Within the limitations of this study:

• Significantly greater wear of both the specimens and the antagonists was detected when a chewing load of 68.6 N (high-load group) was used as compared to a load of 19.6 N (low-load group);

• Higher wear rate of the antagonists was detected as compared to the specimens in both groups;

• In the high-load group, higher wear rate of the specimens was detected in the first 140,000 chewing cycles as compared to the subsequent 140,000 cycles.

As a clinical consequence one may expect more wear of denture teeth in implant supported overdentures than in full dentures.

Author Contributions

JFR: Idea, experimental design, wrote final manuscript. AAN: Performed the experiment as part of the MS requirements, wrote initial manuscript. WM: experimental design, proofread manuscript. NA: supported experimental phase and data production. CS: statistical analysis, proofread manuscript.

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Original Article

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Questions

1. Which teeth were worn?

❑a. Ceramic;
❑b. Double crosslinked PMMA;
❑c. PMMA;
❑d. Composite.

2. Which loads were used?

❑a. 50 and 100 N;
❑b. 20 and 80 N;
❑c. 19.6 and 68.6 N;
❑d. 20 and 50 N.

3. How many load cycles were performed?

❑a. 120,000;
❑b. 240,000;
❑c. 500,000;
❑d. 2,222.

4. Which result is correct?

❑a. The high load group showed significantly higher wear;
❑b. The samples showed more wear than the antagonists;
❑c. The antagonists showed equal wear in both load groups;
❑d. There were no statistically significant differences in wear of the samples.