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Optical Stereometric Analysis of Milled and Not-Milled Copings for Removable Overdentures on an Experimental Partially Edentulous Mandible

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Abstract

Background: This study aimed to examine the effect of differential stress distributions on the occlusal surfaces of the control and experimental copings.
Methods and Results: The study used two master casts of a lower jaw with bilateral terminal edentulous seats. Their topography was identical, indicating a partially edentulous lower jaw according to Eichner's B3 (and C2) classification (i.e., Kennedy class 1). The control cast had conventional oval copings. The experimental cast had the surfaces simulating three specific milled copings covering the remaining tooth substance. Controlled loading was measured using a gnathodynamometer. Loading stages were at 400, 800, and 1000 N. Measurements of strain and displacement were provided by the Digital Image Correlation Method. The "Wilcoxon Lambda" two-sample test was used in the analysis of deformation between the control rounded and experimental milled copings under loading.
Smaller values of deformations were measured on milled copings. There were statistically significant differences in displacement between the control rounded and experimental milled copings ($Pr > |Z| = 0.001$) as well as in deformations ($Pr > |Z| = 0.0298$).
Conclusion: Experimental milled copings are less susceptible to deformation than the control rounded copings. These findings may have clinical significance for improving primary and secondary retention of overdentures on milled copings.(**International Journal of Biomedicine. 2026;16(2):232-241.**)

Keywords:copings • overdenture • shortened dental arch • digital image correlation technique • optic stereometry

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Introduction

To maintain the stability of overdentures, protective copings must be placed over the coronal part of the teeth. This component plays an important role in supporting the alveolar ridge and ensuring proper axial load distribution, thereby helping preserve the alveolar ridge level. Similarly, protective copings preserve the natural tooth roots and improve the stability and retention of overdentures compared to conventional complete dentures.[1-3] Various types of protective copings have been presented to the public.[1-4] In clinical practice, two types of protective copings are commonly used: cast (metallic) and zirconia.[5-8] Cast copings are relatively easy to fabricate but can be associated with clinical problems such as gingival inflammation (69%) and root caries (36%).[3,5] Alternatively, cast copings have the advantage of being provided with a cast post that can be easily inserted into the upper third of the root canal filling, allowing axial load distribution in accordance with the vertical reference axis of the remaining tooth.[3,4] On the other hand, zirconia copings can be very costly and difficult to implement due to the complicated technique, but the periodontal condition around them remains healthy.[3,6] In addition, zirconia copings (the most popular ceramic option) may be susceptible to fractures due to their lower elasticity.[7,8]

Similarly, the different types of interfaces between the denture base and the copings can alter the loading and stress pattern around the abutment teeth.[6,9,10]

Conventional copings usually do not have a milled shoulder for better retention and stress distribution. In this study, a special, simpler form of casted coping was examined on the residual tooth structure in the mandible. These copings functioned both as bone retainers in the surrounding alveolar areas and as retainers for the overdenture. Because they are occlusally designed to have at least some indication of the occlusal relief of the tooth that will support the mandibular prosthesis and because they are milled along the gingival surface, these copings differ from all others previously described in the dental literature. This study was based on an initial assumption and preliminary results indicating that patients in clinical practice were satisfied with the use of these specific coping designs and claimed that they contributed to better retention of their overdenture.[4]

It is still unclear whether the pressure on the copings significantly redistributes the occlusal forces in accordance with the morphologically shaped surfaces corresponding to the occlusal topography and whether it significantly contributes to the stabilization of the prosthesis on the supporting tissues.[4,9-12] We hypothesize that the milled surfaces of the experimental copings may contribute to a better axial load distribution on the roots and that less deformation of the experimental cast copings will improve the stability of the overdentures.

The aim of this study was to examine the effect of differential stress distributions on the occlusal surfaces of the control and experimental copings on artificial casts of partially edentulous jaws.

Materials and Methods

The experiment was accomplished at the Faculty of Mechanical Engineering, University of Belgrade, Serbia. This study included two master casts of a lower jaw with bilateral terminal edentulous seats. Their topography was the same, including missing lower molars, the left lower second premolar, and the right canine and incisors, representing a partially edentulous lower jaw according to the B3 (and C2) classification of Eichner (i.e., Kennedy class 1).

The control cast was designed with conventional oval copings, which are most often used in clinical practice to preserve the remaining dental substance in the crown and to receive the base surface of the overdenture (Figure 1).

Fig. 1. The experimental cast (on the left) and the control cast (on the right).

The experimental cast was almost identical to the control cast, except for the surfaces simulating three specific milled copings covering the remaining tooth structure. The specific copings were shaped to exhibit morphological characteristics of teeth in the occlusal third; they showed discrete, rounded protrusions that partially resembled the cusp tips of natural teeth. In the gingival third, the copings were milled so that the perimeters of each assumed a stepped configuration (forming a ledge or "shoulder"), thereby ensuring retention and stabilization of the base of the corresponding removable prosthesis (Figure 1).

The thickness of all of the resin copings was 3 mm. For the milling of the control and experimental copings, the same armamentarium (surveying device, electrically supplied dental parallelometer with model table, Heraeus CL MF 1000, Germany) and the same procedure were used.

Master casts were fabricated on a 3D printer (Builder Extreme 3000 PRO, Brose, Germany) using a specific photopolymer resin (Photopolymer Resin, Formlabs Inc., Somerville, MA, USA). After the 3D-printed resin printing process was completed, a sufficient post-curing time of at least 60 minutes under different oxygen levels was provided to improve flexural properties and flexural modulus (subsequently, the specimens were submerged in water). The corresponding elastic properties, including the Young's modulus and Poisson ratio, were determined according to the values obtained from the previously published literature.[13,14] The casting surfaces were coated with a thin layer of white paint (Motip Spray, Germany), followed by a thin layer of high-contrast black paint; this was necessary for the correct application of the Digital Image Correlation (DIC) method.

Dots of the spray occupied distances that changed under stress and were registered by cameras.[14,15]

Precise and controlled loading was measured using a dynamometer (Siemens AG, Erlangen, Germany) (Figure 2).[14-18] Axial occlusal loads were applied centrally and vertically to the distal abutment tooth (the first lower premolar), intermediate abutment tooth (canine), and the mesial abutment tooth (the second lower incisor) (Figure 2). The direction of loadings to the second experimental cast was the same. The loading stages were 400, 800, and 1000 N.[14,18]

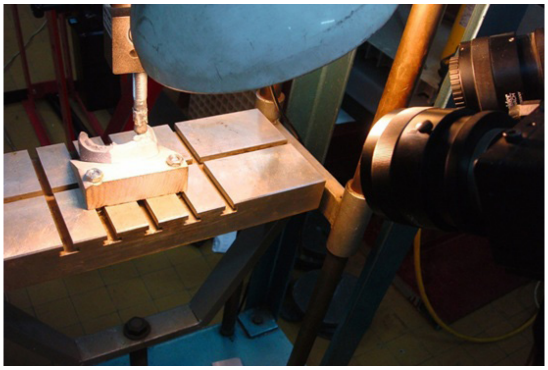

Fig. 2A. *The control cast under the load in a dynamometer.*

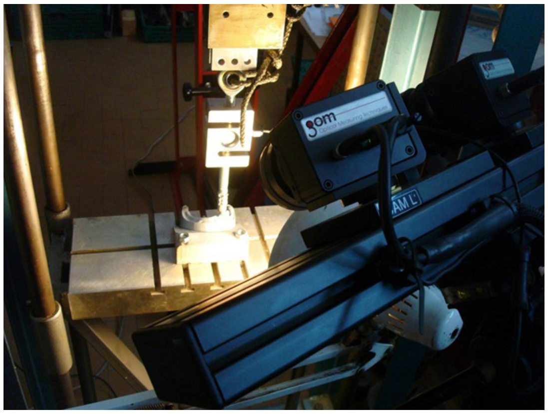

Fig. 2B. *Measurement of the force applied to the coping model.*

Measurements of strain and displacement were obtained using the Digital Image Correlation Method (GOM-Optical Measuring Techniques, Braunschweig, Germany). This system consists of two digital cameras and the associated software ARAMIS (Version 6.2.0; GOM-Optical Measuring Techniques). ARAMIS software, based on the principle of an objective fine-grained procedure, registered 3D changes in the shape and distribution of surface strain on statically- or dynamically loaded objects. Moreover, ARAMIS also determined the shape of the photographed object with high accuracy, its dimensions, its field of 3D motion, the vector of the distorted field, and features of the biomaterial (Figure 3).[14-17]

Mobile cameras captured the distance between the reference points at specified time intervals before the load, during the calibration phase, and during the application of the action force. Before the strains of the control and test copings were measured, a calibration procedure was carried out. To measure the 3D strains, two cameras were manually positioned and adjusted to the measurement volume of the calibration object. The strains within the selected area could be measured over a range from 0.01% to several hundred percent, and the strain measurement accuracy was up to 0.01%.[14,15]

Small and large objects, from 1.00 to 2000.00 mm, could be measured with the same sensor.[14] The software processing of the data measured enabled recording of the results and a 3D presentation (Figure 3).[14-16]

Statistical analysis: Descriptive statistics were used to visualize the results regarding the deformation and displacement of the tooth copings obtained in this experiment. The MEANS procedure from the SAS statistical package (SAS Institute [2010]) was used for the analysis. Wilcoxon lambda tests based on simple linear rank statistics were used to analyze the numerical values of the copings' deformations and displacements. The mean value was used as a measure of central tendency. To identify differences in the mean values of the parameters between the experimental and control caps, nonparametric statistical methods were employed based on the response variable (percentage of deformation and displacement).

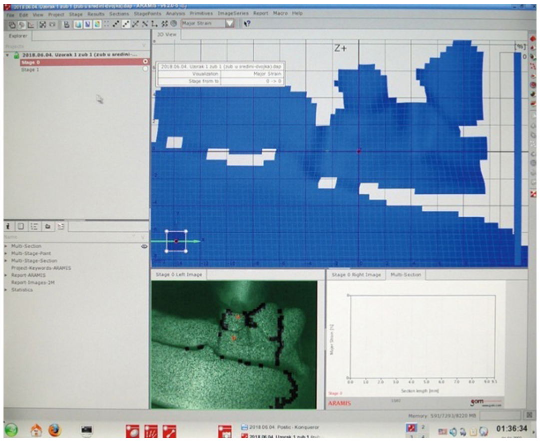

Fig. 3A. *The borders of areas of interest for the experiment.*

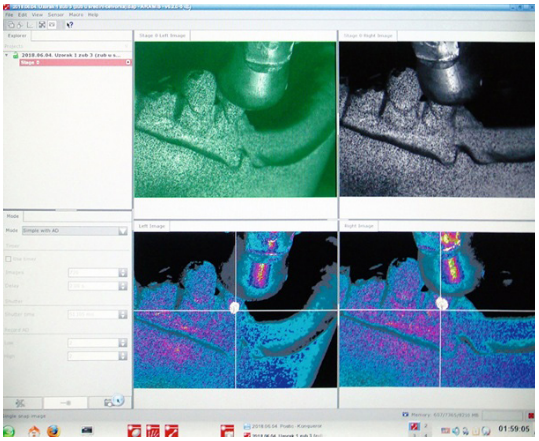

Fig.3B. *The active surface of the dynamometer, displayed on the screen during the measurement of the force directed on the coping.*

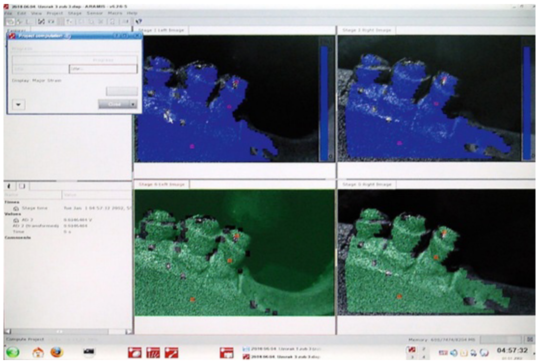

Fig.3C. *The appearance of milled coping models in computer software.*

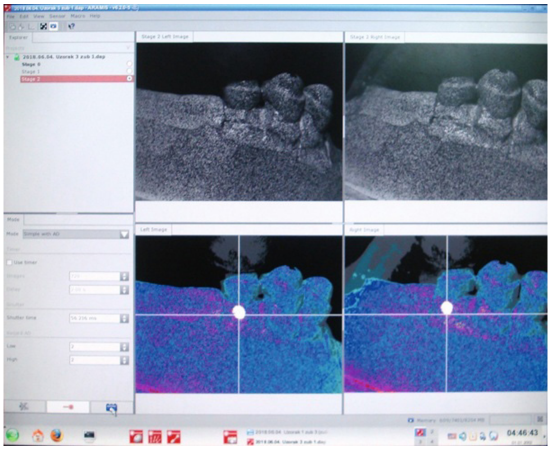

Fig. 3D. *Vector of the forces applied.*

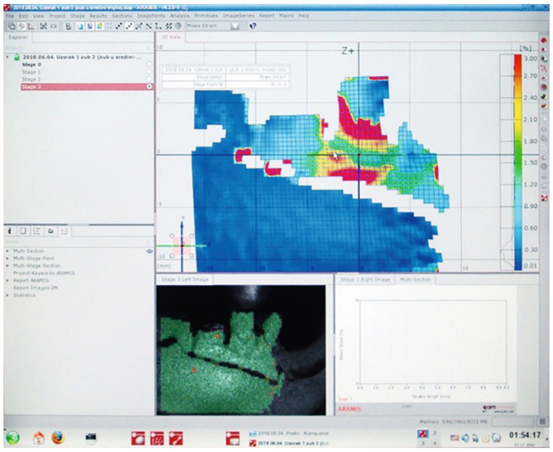

Fig. 3E. *The terminal zone of the crack (red areas).*

Results

Stress and deformation of the cast copings investigated in the present study were distributed differently. We found that the most intense deformations occurred under the actual force transmitted to the border of the coping and the immediate area of remaining tooth substance.

Significantly lower displacements were recorded in the group of teeth with experimental milled copings compared to the control group with rounded copings (Figures 4 and 5). These results were consistent across all three loading stages and across all tooth types investigated.

The deformation measures were smaller for the milled copings than for the control copings (Tables 1 and 2). There was a direct link between the percent of coping deformation and the type of coping. The type of coping was a significant determinant of the degree of tooth-coping displacement under pressure in this experiment. There were statistically significant differences in displacement between the control rounded and experimental milled copings (Pr > |Z| = 0.001) as well as in deformations (Pr > |Z| = 0.0298) (Table 3). The shape of the non-milled coping is directly responsible for the movements and cracks in the gum area.

There was significant deformation in the control rounded tooth coping when compared to the experimental milled tooth coping. These findings were observed at a pressure of 1000 N, regardless of the type of teeth evaluated (Figures 6 and 7).

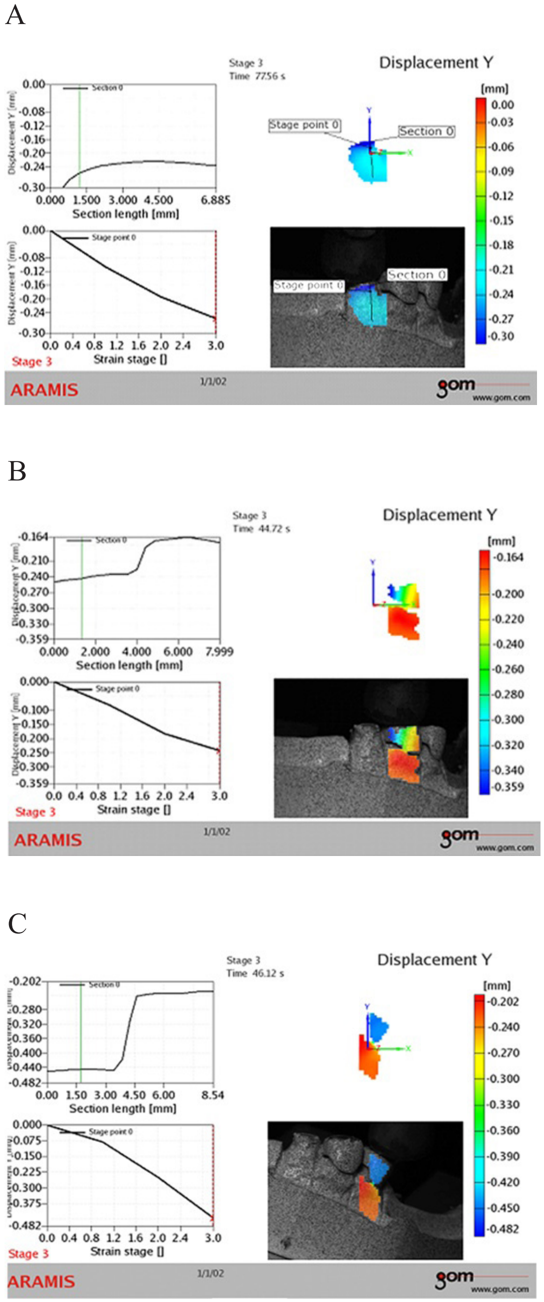

Fig. 4. *Displacement of the remaining teeth covered by the control copings. A) Displacement within the incisor with control coping under loading of 1.000 N (Final Stage 3); Upper left panel–final stage; lower left panel– initial stage; right panel– distribution of loads and stresses along and within the coping of the control incisor; B) Displacements within the control canine with coping under loading of 1.000 N (Final Stage 3); upper left panel– final stage; lower left panel– initial stage; right panel– distribution of loads and stresses along and within the coping of the control canine; C) Displacement within the coping of the premolar under loading of 1.000 N (Final Stage 3); upper left panel– final stage; lower left panel– initial stage; right panel– distribution of the loads and stresses along and within the control coping of the premolar.*

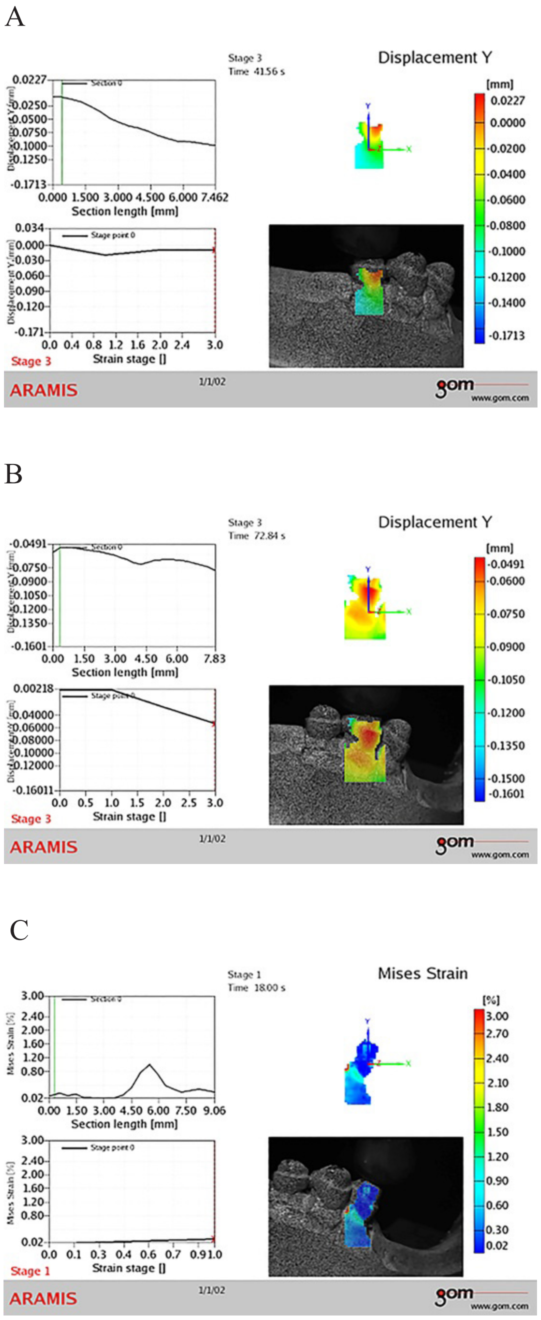

Fig. 5. *Displacement of the remaining teeth covered by the experimental copings. A) Displacement within the milled coping of the incisor under loading of 1.000 N (Final Stage 3); upper left panel– final stage; lower left panel– initial stage; right panel– distribution of loads and stresses along and within the experimental milled coping of the incisor; B) Displacement within the experimental coping of the canine under loading of 1.000 N (Final Stage 3); upper left panel– final stage; lower left panel– initial stage; right panel– distribution of loads and stresses along and within the experimental milled coping of the canine; C) Displacement within the experimental milled coping of the premolar under loading of 1.000 N (Final Stage 3); upper left panel– final stage; lower left panel– initial stage; right panel– distribution of loads and stresses along and within the experimental milled coping of the premolar.*

Table 1.

Maximum deformation of the control conventional oval copings on the incisor, canine, and premolar.

Stage	Points							
Name (Sub-project: Point-ID)	Facets XY	Actual data (mm)	Coordinate X	(Deformed) Y	Z (mm)	Coordinate X	(Undefomed) Y	Z (mm)
Incisor with conventional oval coping	0.4	+3.39	+0.57	+0.98	-1.65	+0.55	+1.24	+1.47
Canine with conventional oval coping	0.3	+0.51	+6.56	+1.86	-1.64	+6.57	+2.10	-1.39
Premolar with conventional oval coping	0.5	-0.39	+1.14	+3.29	0.99	+0.75	+3.74	+1.30

Table 2.

Maximum deformation of the experimental milled copings on the incisor, canine, and premolar.

Stage	Points							
Name (Sub-project: Point-ID)	Facets XY	Actual data (mm)	Coordinate X	(Deformed) Y	Z (mm)	Coordinate X	(Undeformed) Y	Z (mm)
Incisor with experimental milled coping	0.2	+0.12	+0.52	+3.75	-0.33	+0.53	+3.76	+0.23
Canine with experimental milled coping	0.1	+0.10	-0.12	+4.42	-1.57	-0.19	+4.47	-1.18
Premolar with experimental milled coping	0.1	+0.13	-0.61	+1.88	-2.12	-0.69	+1.87	-1.94

Table 3.

Differences in the displacement and deformation between the control rounded and experimental milled copings of the remaining tooth substances under loading.

	Displacement	Deformation
Type of coping	Mean score	
Round	5.0	10.0
Milled	13.0	5.0
Normal Approximation Z	3.2814	2.1722
Two-Sided Pr > |Z|	0.0010*	0.0298*

**Wilcoxon Two-Sample Test.*

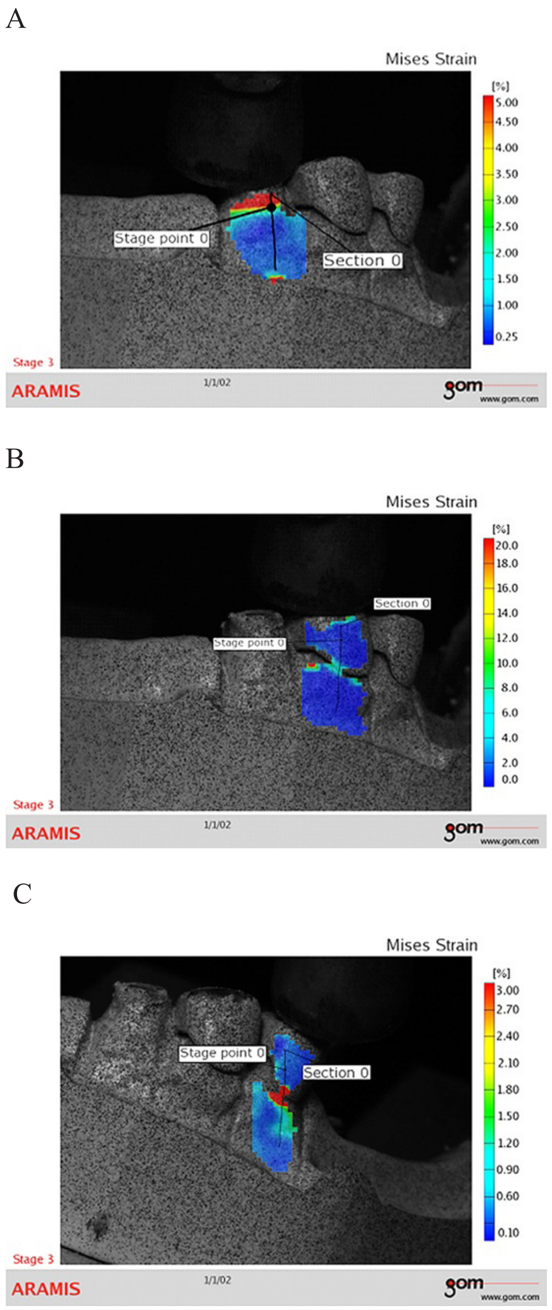

Fig. 6. *A) von Misses strain of the control coping of the incisor; B) von Mises strain of the control coping of the canine; C) von Mises strain of the control coping of the premolar.*

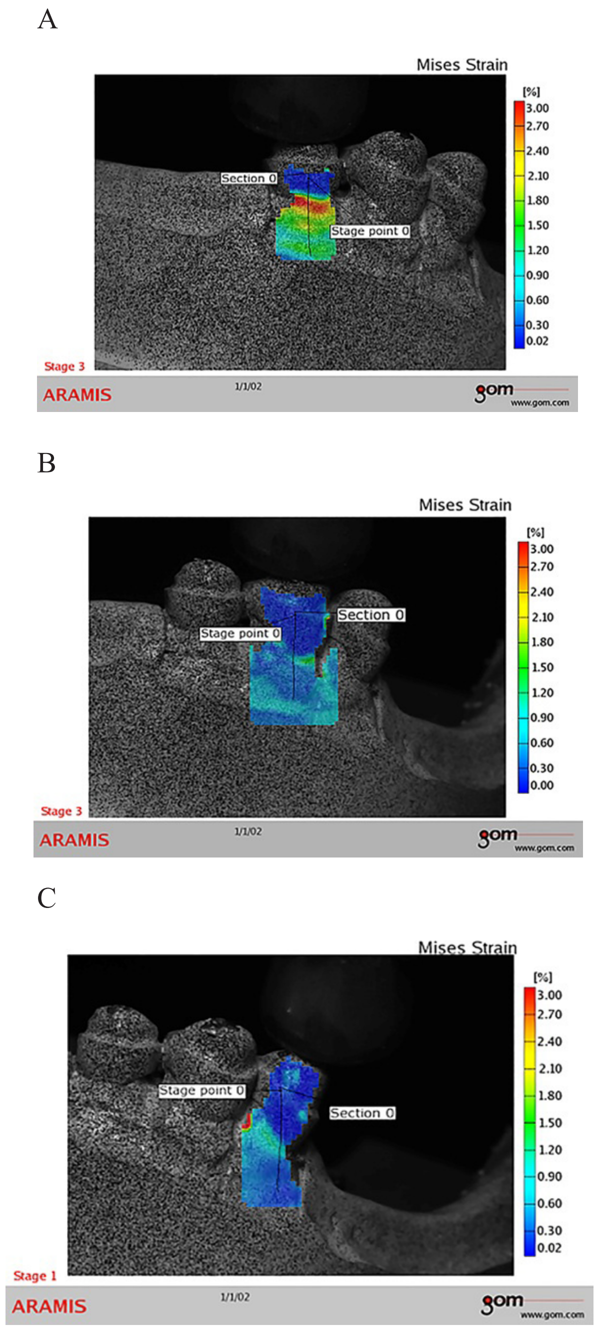

Fig. 7. *A) von Mises strain of the experimental coping of the incisor; B) von Mises strain of the experimental coping of the canine; C) von Mises strain of the experimental coping of the premolar.*

Discussion

Currently, overdentures are recommended in cases where a significant loss of the alveolar ridge is observed following multiple tooth extractions.[4,19]

Preservation of the alveolar bone and stabilization of the prosthesis can be achieved by covering the remaining teeth with copings.[3,5] Furthermore, it remains unclear why the remaining teeth in our study were present only on one side of the mandible, given the known problem that the remaining tooth structure may be exposed to an "additional load" on the edentulous side of the mandible.[4] This experiment was performed on a partially edentulous mandible of Kennedy Class 1 (i.e., Eichner's B3 [and C2] classification), as this type of partially edentulous mandible is the most common in clinical practice.[20] This type of partial edentulism is also relatively difficult to treat therapeutically.[3,4]

In this study, significantly higher deformation values were observed for the rounded control copings compared to the experimentally milled copings. The higher deformation values of the rounded copings could be explained by their spherical surface. More specifically, the axial force acting on a spherical surface consists of two components: tangential and normal. The tangential component was the main cause of the deformation of the rounded oval control copings. However, only axial forces occurred in the milled copings, which led to significantly lower deformation. In our study, the displacement of milled copings was significantly higher than that of the rounded control copings. This result could be explained by the fact that all forces acting on milled copings were distributed axially.[4]

Researchers in dental prosthetics have long debated the issue of stability.[21] It is assumed that the morphologically developed occlusal sections of the experiment, intended only for milling copings, redirect forces precisely along the axial axis, resulting in a medically favorable load. Furthermore, it was assumed that the occlusal plateau, with the largest surface area, practically absorbs all loads (both physiological and caustic) almost completely. All other stresses that exist within an orofacial system, while the axial surfaces of custom-milled copings, with the exception of the shoulder area, would be significantly or completely relieved of tensile stresses, as found in a previous study.[20] The results of the present study did not fully confirm these assumptions; however, they demonstrated that the degree of deformation in the experimental milled copings was significantly lower.

In addition, preliminary studies on the outcomes of overdenture therapy found that both patients and the therapists evaluating success considered the prostheses resting on milled special copings of the roots of the remaining retained maxillary teeth to be quite stable.[22]

In addition, better direct and indirect stabilization of the prosthesis was achieved compared with the conventional coping shape.[4] Thus, the milled shoulder of the coping may increase the likelihood of additional retention when picking up the basal surface of the overdenture. From these findings and the loading shown (Figures 7 and 6), we cannot conclude that the milled surfaces absorb and amortize (redirect in axial and centric directions) the forces acting on the milled copings to the greatest extent. The results only show that the numerical amount of deformation in the cervical segments of the specially milled copings (Tables 1-3) was less than that of the conventional control copings.

The results of this study raise the question of whether the forces, stresses, and deformations were greatest at the top of the coping, thereby distributing the load and exerting vertical pressure on the tooth root. The present study analyzed cast copings and found that the distribution of stresses and deformations varied between them. We found that the most intense deformations occurred under the actual force transmitted to the margin of the coping and the immediate area of the remaining tooth structure. Considering that the stress was highest in the area of the element with the largest diameter, the cause of the most severe deformations at the cervical margin of the copings can be attributed to the maximum stress at this location.

Previous research on the difficulties of implementing the stereoptic (stereometric) approach has shown the usefulness of the method in some dental specialties.[24-34] With this stereo-optical method, when two cameras are installed, one can ensure that points in two images can be matched and autostereograms can be created using information about corresponding points based on the initially separated positions of the two cameras. Thus, the 3D positions of objects can be determined.[25,35,36] The stereo-optical (stereometric) method thus appears to be reliable for assessing stresses and deformations.

The resemblance between the experimental milling copings and constructs based on the ferrule effect concept lends credence to these arguments. It has already been shown that the fabrication of milled metal copings with the addition of a post emphasizes the beneficial effects of preventing the independent flexure of tooth or core/post structures.[7] Such structures are located within the supra-ferrule-margin volume of the tooth; if a force is applied to the tooth, the entire supra-ferrule-margin tooth, core, and post complex work as one unit to resist the force.[4,37]

The results of our study showed that the oval control copings were less resilient compared to the experimental milled copings. Since, to the best of our knowledge, this study represents the first investigation to employ stereoptic assessment of the shape of specialized caps, comparing the obtained results with data from other studies is extremely difficult.

This is because there is no relevant data on the effect of forces and deformations for these purposes. The results of the present study are consistent with those of other authors, who argued that metal coping has the highest degree of stress transfer to the load-bearing web. The reason for this lies in the properties of metals, which are characterized by high hardness and rigidity; these characteristics create a robust foundation for the prosthetic structure, ensure that the majority of the applied load is transmitted to the supporting teeth (abutments), and reduce the level of stress in the region of the supporting alveolar ridge.[38]

It is certain that the most desirable criterion for selecting the attachment system for overdentures is the way these attachments transfer loads to the supporting structures (Figure 8). The distribution of stress through the abutments in an arch-spanning manner and between the abutments and the posterior edentulous ridge is always favorable for the preservation of the residual ridge. To ensure the most effective distribution of stresses, the optimal solution is to design a retention system for the overdenture that maximizes load distribution between the retention element and the residual alveolar ridge.[39]

Fig. 8. *An acrylic overdenture fabricated to correspond to the copings and supporting tissues of the jaw.*

The high values of the loads (400N, 800N, and 1000N) utilized in this study are addressed in the limitations of this experimental investigation, keeping in mind that the mean occlusal loads on the premolars ranged from 39 to 66 N, and on the front teeth (apart from bruxism) from 11 to 33 N [28,40,41] with a limitation of the type of force applied and the duration of its application.

Conclusion

The results of this study underscore the need to use protective caps as extracoronal structures for teeth remaining beneath removable overdentures. Based on the results of this study, there will be an implicit demand in clinical practice to position protective copings as an extracoronal construction of remaining teeth under overdentures. Experimental milled copings are less susceptible to deformation than the control rounded copings. These findings may have clinical significance for improving primary and secondary retention of overdentures on milled copings.

Clinical Implications

There is the implicit demand in clinical practice to position protective copings as an extracoronal construction of remaining tooth substance under overdentures. Specially designed, dedicated experimental milled copings are expected to improve primary and secondary retention of overdentures. The study has a limitation because it evaluates occlusal stress distribution on master casts, which cannot replicate the functional adaptation of the periodontal ligament.

Ethics Statement

This study was conducted in laboratory conditions as an investigation on materials in in vitro conditions. No human or animal models were used.

Statement of the Authors

The materials of this study were previously published as preprints and preliminary results, and are included in the bibliography of the present manuscript as References 14,15,16 and 17.

Author Contributions

Srđan D. Poštić: Conceptualization, Methodology, Investigation, Data curation.

Slobodan Dodić: Investigation, Data curation.

Ivan V. Tanasić: Investigation, Data curation, Writing – review and editing.

Miloš Milošević: Investigation, Data curation and interpretation.

Stevan Avramov: Data curation, Formal analysis, Writing – original draft.

Vladimir Biočanin: Investigation, Writing – review and editing.

Ljubiša Ristić: Data interpretation, Writing – original draft.

Igor Đorđević: Data interpretation, Writing – original draft.

Aleksa Milovanović: Data curation, Formal analysis.

Miloš Maksimović: Investigation, Writing – review and editing.

Ekatarina Ž. Džigurski: Investigation, Data curation.

Predrag M. Šojić: Investigation, Data curation.

All authors have approved the final article.

Conflict of Interests

The authors have declared no conflict of interest.

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