Anteroposterior Spread and Cantilever Length in Mandibular Metal-Resin Implant-Fixed Complete Dental Prostheses: A 7- to 9-Year Analysis

Bradley A. Purcell, DDS, MS[a]/Edwin A. McGlumphy, DDS, MS[b]/Burak Yilmaz, DDS, PhD[c]/
Julie A. Holloway, DDS, MS[d]/Frank M. Beck, DDS, MA[e]

Purpose: The purpose of this retrospective study was to investigate the relationship of specific prosthetic complications in patients with a maxillary complete removable dental prosthesis (CRDP) opposing a mandibular metal-resin implant-fixed complete dental prosthesis (MRIFCDP) with respect to anteroposterior (AP) spread and cantilever length. ***Materials and Methods:*** Of the 46 patients contacted for this study, 23 patients responded. All patients had been treated with a maxillary CRDP and a mandibular MRIFCDP. They were reviewed for prosthetic complications, and the AP spread and cantilever length were evaluated. A polyvinyl siloxane impression was made of each MRIFCDP so that cantilever length and AP spread could be measured. The average recall time was 8.5 years. The mechanical complications noted were screw-related complications, including both the prosthetic and the abutment screw, consisting of loosening and/or fracture, and fracture of the metal framework. Three different individuals repeated each measurement three times. Inter- and intrarater reliability was evaluated with the intraclass correlation coefficient, and a linear regression analysis of age and average cantilever length to AP spread ratio was calculated. In addition, calculations using this ratio were divided into two groups (> 2.1 and ≤ 2.1) and examined with each variable individually. A logistic regression analysis was performed for a comparison between the two AP spread ratio groups by age, right cantilever length, left cantilever length, average cantilever length, posterior spread, and failures. ***Results:*** None of the predictor values was significant for the linear regression analysis of age, cantilever length, and AP ratio on number of failures. There was no significance in complications between the groups that had an AP spread ratio > 2.1 and groups that had an AP spread ratio ≤ 2.1. ***Conclusions:*** There was no statistical significance in predicting whether a screw-related complication would occur in relation to age, cantilever length, or AP spread ratio. There was no increase or decrease in complications whether the AP spread ratio was greater than or less than or equal to 2.1. In mandibular MRIFCDPs opposing maxillary complete denture situations, screw-related complications may be less likely regardless of the patient's age, cantilever length, or AP spread ratio of the prosthesis. *Int J Prosthodont 2015;28:512–518. doi: 10.11607/ijp.4172*

Anteroposterior (AP) spread, as described by English, is the distance between two lines: a line drawn connecting the posterior aspect of the two most distal implants and a mediolateral line through the middle of the most anterior implant.[1] This spread is determined by the surgical placement of the implants and the arch-form of the patient. This distance has been proposed to use to determine the cantilever lengths of implant complete dental prostheses.

A cantilever prosthesis undergoes two main directions of loading: axial and bending.[2] The bending moments exert localized high-stress gradients in the implant and the bone, whereas the axial force distributes stress more evenly throughout the implant.[2] Bending moments are the product of the force and the Class I lever arm. As force is applied in the posterior, the anterior implant will absorb a tension force proportional to the lever arm ratio of cantilever lengths anterior and posterior to the fulcrum and

[a]*Private Practice, Worthington, Ohio, USA.*
[b]*Professor, Division of Restorative and Prosthetic Dentistry, Ohio State University, Columbus, Ohio, USA.*
[c]*Associate Professor, Division of Restorative and Prosthetic Dentistry, Ohio State University, Columbus, Ohio, USA.*
[d]*Head, Department of Prosthodontics, University of Iowa College of Dentistry, Iowa City, Iowa, USA.*
[e]*Associate Professor, Section of Oral Biology, Ohio State University, Columbus, Ohio, USA.*

Correspondence to: *Dr Burak Yilmaz, Ohio State University College of Dentistry, Division of Restorative and Prosthetic Dentistry, Columbus, Ohio 43210, USA. Fax: 614 292-9422. Email: yilmaz.16@osu.edu*

the posterior implant will have a compression force that is the sum of the applied occlusal force and the compensation tension force.[2] The tension force is the one that separates the units and is therefore the important one with regard to failures and complications. Therefore, the most critical determinant in the success or failure of the unit is the ratio of cantilever length to the AP spread.

White et al[3] and Kim et al[4] showed, through photoelastic studies, that as loads were placed on cantilevers there was a concentration of stress fringes around the crestal bone of the distal implant. Additionally, it was shown in White et al's study that as the cantilever length was increased, there was an increase in stress around the distal implant.[3] However, the increase in stress on the bone was not proportional with the increase in load. In fact, the stress with increased load was less.[3] Weinberg stated that when force is placed on the cantilever, the force is exerted mostly in the prosthetic components rather than in the implants themselves.[5] Thus, concerns regarding implant failure should be shifted to prosthetic complications.[5]

To date, no scientific or proven formulas have been determined to optimize the length of the distal extensions. Several authors have postulated formulas or rules to determine a clinically acceptable cantilever length. Rangert and Sullivan stated that the cantilever length could be 15 to 20 mm in the mandible and no more than 10 mm in the maxilla.[6] Takayama calculated the cantilever length and took into account the implant length. He based the calculations on five implants with a center-to-center fixture separation, and stated that the cantilever portion should be less than 2 times a 10-mm AP spread.[7] English stated that a reasonable guideline to follow for five implants was 1.5 times the AP spread for the mandible, and a shorter cantilever of 6 to 8 mm should be considered for the maxilla due to the poor bone quality.[1] Numerous other proposals on cantilever lengths in the mandibular arch have been recommended in the literature. Suggestions include 20 mm,[8,9] not exceeding 20 mm,[10–13] no more than 20 mm and best kept under 15 mm,[14] 18 to 20 mm,[15] 15 to 20 mm,[16] and the equivalent of the width of two teeth placed distal to the most posterior abutment.[17,18] Studies have been performed to relate cantilever length and marginal bone loss around implants, but few studies have been performed to relate cantilever length to the survival of mandibular metal-resin implant-fixed complete dental prostheses (MRIFCDPs).[17–20] In a prospective 10-year cohort study, Fischer and Stenberg[18] evaluated the prosthetic outcomes and maintenance of MRIFCDPs in the edentulous maxilla. The authors stated that the length of cantilevers did not confer additional risk on the survival of the MRIFCDPs. Shackleton et al studied the survival of MRIFCDPs with respect to cantilever length. They found a significantly better survival rate over an 80-month time period in prostheses with a cantilever length less than 15 mm compared to those with a cantilever length greater than 15 mm.[19] However, this study made no mention of the AP spread of any of the prostheses. Gallucci et al[20] evaluated the 5-year survival rate, success rate, and primary complications associated with mandibular MRIFCDPs with distal cantilevers averaging 15 mm in length. They reported no clear trends between increased length of the distal cantilevers and number or type of complications experienced. Twenty out of 45 patients in their study had cantilevers of lengths $\geq$ 18 mm. Complications experienced in their study were classified only as biological and were resolved.

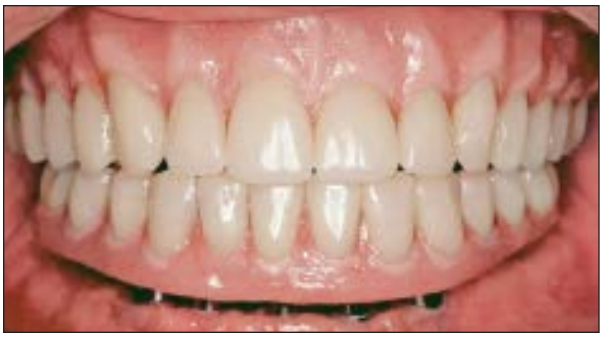

Fig 1 Maxillary complete denture opposed by an MRIFCDP.

The purpose of the present study was to investigate the relationship of specific prosthetic complications in patients with a maxillary complete removable dental prosthesis (CRDP) opposing a mandibular MRIFCDP with respect to AP spread and cantilever length.

Materials and Methods

The patients in this study are a subset from an ongoing prospective clinical trial evaluating implant and soft tissue complications and a subset of a previous retrospective study (46 patients) that evaluated prosthetic complications of maxillary CDRPs opposed by mandibular MRIFCDPs (Fig 1).[21] A total of 23 patients out of 46 responded to an invitation to be involved in this study. All of the patients in this subset were restored with maxillary CDRPs opposed by mandibular MRIFCDPs and were edentulous prior to entering the study. All patients were treated with a maxillary CDRP fabricated with acrylic resin bases and acrylic resin denture teeth. Three patients had six implants placed and 20 patients had five implants placed. These implants were standard external hexagon Steri-Oss Implants (NobelBiocare) placed in the anterior mandible between the mental foramina. The implant surfaces included the following: hydroxyapatite

(HA)-coated threaded, HA-coated cylindrical, and titanium alloy machined surface threaded endosseous implants.[13] Each patient then received a mandibular MRIFCDP with the following components: Steri-Oss PME (NobelBiocare) transmucosal abutments, cast-to prosthetic copings (60% Au, 20% Pd, 19% Pt, and 1% Ir) with a hexed coping screw (titanium alloy), a cast metal alloy frame (as described below), acrylic resin denture teeth, and heat-processed acrylic resin.

Twenty patients had 5 mandibular implants and 3 had 6 mandibular implants placed and restored for a total of 118 Steri-Oss implants in the evaluation. Implant diameters ranged from 3.25 to 4.5 mm, and lengths varied from 8 to 18 mm. The superstructure frameworks of the MRIFCDPs were constructed of various metal alloys: 18 Type III Au alloy, 3 Type IV Au alloy, and 2 Au-Pd alloys. Each framework was L-shaped in design with exposed metal gingival surface. Acrylic wraparound design was not used in any of the patients. Each patient had acrylic resin denture teeth, which were attached to the framework with heat-processed acrylic resin. The acrylic resin denture teeth varied in brand, and the heat-processed acrylic resin varied in type. The brand of prosthetic teeth and acrylic resin were not noted for the majority of the patients.

All 23 patients received a new maxillary CRDP the day the mandibular prosthesis was inserted. All 23 patients had the same acrylic resin denture bases and acrylic resin denture teeth that they had in their mandibular MRIFCDPs. Additionally, all of the CRDPs were entirely acrylic resin based, and no metal-based CRDPs were made.

Once the second stage surgery was completed, the tissue thickness was measured and an appropriate abutment cuff height was chosen. The abutments were placed and torqued to 30 Ncm. Maxillary and mandibular final impressions were made. In the maxillary arch, a border-molded custom tray was used and an abutment level impression of the mandibular arch was made. At the next appointment, the casts were mounted in centric relation (CR) at the proper vertical dimension of occlusion (VDO), using maxillary record bases with wax rims and mandibular implant-secured record bases with wax rims. Acrylic resin denture teeth were set. CR, VDO, esthetics, and phonetics were verified. The framework was cast in the respective metal alloy for each patient and then tried in for passive fit. Passivity was verified by a combination of methods: the one screw test, radiographically with a panoramic radiograph, and/or visually.[22,23] The frameworks were sectioned and soldered as necessary until a passive fit was determined. One laboratory technician fabricated all of the metal frameworks. Cantilever lengths were determined so that at least first molar occlusion was achieved. As a result, cantilever lengths varied from patient to patient and within patients depending on maxillomandibular relationship, mandibular arch shape, and implant position. AP spread ratio was not used as a main determinant of distal cantilever length. The teeth were then reset onto the framework, and CR, VDO, esthetics, and phonetics were again verified. The maxillary and mandibular prostheses were processed with heat-cured acrylic resin. The frameworks were not treated to increase the resin-to-metal bond, nor were retentive features added to the prosthetic denture teeth or wax solvent used during processing. The occlusal scheme for all of the prostheses was set to bilateral simultaneous posterior contacts in CR with bilateral balanced occlusion in excursive movements. At the final appointment the maxillary and mandibular prostheses were inserted, with a clinical remount if deemed necessary. Prosthetic screws were tightened to 20 Ncm, and the access hole filled with cotton pellets and a polyester urethane dimethacrylate composite resin (Fermit, Ivoclar Vivadent). The patients were then seen for 24-hour recall. One clinician supervised all stages of the prosthesis fabrication and recall appointments for each patient in the Implant Clinic at the Ohio State University. Recall appointments were performed over the following intervals: 3, 6, 9, and 12 months, and then annually, except where additional appointments were needed as a result of complications. At each scheduled recall appointment, the mandibular prosthesis was removed and replaced with the existing retaining screws at 20 Ncm torque. Subsequently, the access holes were filled with cotton pellets and a polyester urethane dimethacrylate composite resin.

All patient records were retrospectively reviewed for complications and dates when the complications occurred. Dates of each complication were noted with respect to the dates the prostheses were inserted. Each complication that was noted is listed below with an associated definition when necessary (Table 1). Complications were counted on a by-appointment basis. If one or several of the complications was found or reported on recall, one complication was noted in the data table.

An attempt was made to reach each patient from the aforementioned retrospective study to make impressions of the MRIFCDP. Of the 46 patients, 23 were able to return for the impression (6 men and 17 women). The mean recall period was 8.5 years with a range of 7.1 to 9.7 years. At this appointment, the mandibular prosthesis was removed and a type I, very high viscosity polyvinyl siloxane impression (Reprosil, Dentsply Caulk) was made to capture each implant/abutment location and the termination of the distal extensions.

Table 1 The Complications Considered in the Present Study

Complication	Definition
Implant failure	Any implant failure or fracture resulting in prosthetic disuse
Abutment screw loosening	When the abutment screw can be further tightened with the use of a driver and finger torque
Abutment screw fracture	A fracture of the abutment screw
Retaining screw fracture	A fracture of the retaining screw
Retaining screw loosening	When the retaining screw can be further tightened with the use of a driver and finger torque

Three individuals (raters) then made measurements three separate times on three separate days. For the right cantilever length, the individuals measured from the distal extent of the most posterior abutment to the terminus of the distal cantilever on the patient's right side of the impression. For the left cantilever length, the raters measured from the distal extent of the most posterior abutment to the terminus of the distal cantilever on the patient's left side of the impression. For the AP spread measurements, the raters measured from the center of the most anterior abutment to the middle of a line drawn from the distal aspect of the right and left abutment. For the posterior spread, the raters measured from the middle of a line connecting the distal aspect of the right and left distal abutments to the middle of a line connecting the distal aspect of the right and left distal extensions.

The dimensions, to the nearest 0.01 mm, were measured by a digital micrometer (Mitutoyo) and the data were recorded (Fig 2). Subsequently, three measurements made by each rater for each category listed above were averaged.

The average measurements within each category were averaged between each rater. The values obtained were average right cantilever length, average left cantilever length, average AP spread (APS_{avg}), and average posterior spread (PS_{avg}). Then, the AP spread ratio (APS ratio) was obtained for each patient by dividing the PS_{avg} by the APS_{avg}.

$$\text{APS ratio} = PS_{avg}/APS_{avg}$$

Two AP spread ratio groups were established: Group I (high): AP spread ratio $\leq$ 2.1, and Group II (low): AP spread ratio $>$ 2.1.

The average inter- and intrarater correlation coefficients (ICCs) were calculated to evaluate the reliability of the measurements of the raters. Linear regression analysis was used for the relationship between the number of failures and age, average cantilever length, and AP ratio. Logistic regression analysis was performed for a comparison between two AP spread ratio groups against age, right cantilever length, left cantilever length, average cantilever length, posterior spread, and failures.

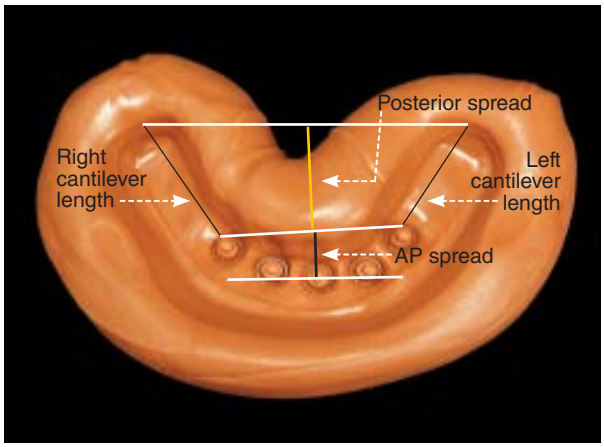

Fig 2 Polyvinyl siloxane impression of a mandibular prosthesis.

Results

Table 2 represents the average ICCs and their 95% confidence intervals. The high ICC for interrater reliability was 0.99 for the left cantilever measurement, with the low ICC being 0.91 for AP spread. The high ICC for the intrarater reliability was 0.99 for left cantilever length, and the low ICC was 0.95 for the AP spread.

Four possible complications were used in the data (Table 1). None of the superstructures suffered from bending or fracture. After all prostheses were inserted, only one implant failed. The failed implant was the distal implant on the right side and was discovered at the 6-year recall. This implant was not replaced. All original prostheses were in service at the time of the patient's most recent recall appointment, for 100% continuous prosthesis success.

None of the predictor values for the linear regression analysis of age, cantilever length (an average of left and right cantilever length), and AP ratio on number of failures were significant (Table 3). When the AP spread ratio was divided into two groups ($>$ 2.1 and $\leq$ 2.1) and examined with each variable individually, there was no significance between the two groups (Table 4).

Table 2 Reliability Coefficients

	Interrater			Intrarater		
	ICC	LCB (.95)	UCB (.95)	ICC	LCB (.95)	UCB (.95)
Right cantilever length	0.97	0.93	0.98	0.98	0.97	0.99
Left cantilever length	0.99	0.97	0.99	0.99	0.98	0.99
AP spread	0.91	0.76	0.94	0.95	0.91	0.97
Posterior spread	0.94	0.84	0.96	0.97	0.95	0.99

ICC = intraclass correlation coefficient; LCB = lower class boundary; UCB = upper class boundary.

Table 3 Linear Regression for Number of Failures

Variable	*df*	Parameter estimate	Standard error	*t*	Pr > |*t*|
Intercept	1	−2.37153	2.28065	−1.04	0.3115
Age	1	0.01864	0.03368	0.55	0.5864
Cantilever length	1	0.06992	0.08409	0.83	0.4161
AP ratio	1	0.22715	0.5534	0.41	0.6861

Table 4 Means and Standard Deviations, Minimums, and Maximums for Age, Right Cantilever Length, Left Cantilever Length, Average Cantilever Length, Posterior Spread, and Failures for High AP Spread and Low AP Spread Group Comparisons

	High AP (> 2.1)					Low AP (≤ 2.1)							
Variable	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	*df*	*t*	Pr > |*t*|
Age (y)	12	57.92	8.33	44.00	71.00	11	58.27	4.78	53.00	68.00	21	−0.12	0.9024
Right cantilever length (mm)	12	21.38	3.42	17.70	28.00	11	20.41	2.39	17.27	26.02	21	0.79	0.4405
Left cantilever length (mm)	12	20.61	4.47	15.15	29.01	11	19.86	3.24	13.45	25.39	21	0.45	0.6541
Average cantilever length (mm)	12	21.00	3.74	16.70	28.50	11	20.14	2.46	17.18	25.70	21	0.65	0.5254
Posterior spread (mm)	12	18.99	3.55	14.45	25.94	11	18.25	2.75	14.19	23.35	21	0.56	0.5844
Failures	12	0.75	1.29	0.00	4.00	11	0.55	0.69	0.00	2.00	21	0.47	0.6443

Discussion

This retrospective study investigated the relationship of specific prosthetic complications in patients with a maxillary CRDP opposing a mandibular MRIFCDP with respect to AP spread and cantilever length. It appeared that the odds of having a screw complication were the same regardless of the age of the patient, the cantilever length of the prosthesis, or the AP spread ratio. This finding may be clinically significant.

The intra- and interrater reliability results showed that the raters had excellent reliability for measurements of the dimensions. This shows that the raters were consistent with their own measurements and that each rater's measurements were consistent with those of the other two raters.

In this study, the subjects were divided into two groups: those with an AP spread ratio of > 2.1 and those with an AP spread ratio of ≤ 2.1. Despite the notion that a greater AP spread ratio will result in more screw complications, implant failures, or superstructure fractures, this study did not reveal this to be true. The results of this study agree with the results of Shackleton et al's[19] and Gallucci et al's[20] clinical studies.

There are a number of variables related to mechanical complications. These include, along with AP spread, occlusion and the antagonistic arch, vertical dimension and/or prosthesis height/implant ratio, implant system, implant connection design and/or implant materials, framework design, framework fit, patient occlusal force, and parafunctional habits.[7] Therefore, the conclusions of this paper must be considered in the context of the difficulties in isolating AP spread as a single controlling variable. When the antagonist arch was considered, Gallucci et al's[20] subjects were edentulous with complete dentures in the maxillary arch, and Shackleton et al[19] included only four implant restorations in the antagonist arch. Shackleton et al did observe, however, that > 15 mm

of cantilever length led to higher mechanical complications, and Gallucci et al's[20] population had an average cantilever length of 15.6 mm. The results of the current study were obtained from MRIFCDPs with a mean cantilever length of 20.58 mm.

The patients in the present study had either five or six implants. It is not possible to make strong conclusions for patients with other numbers of implants, such as those with only four implants, which is the current trend. The implant used in this study was Ti alloy. Systems that use commercially pure or gold materials may have more complications than what has been demonstrated in this evaluation. The implants used in this study were also external hex in abutment connection. Therefore, again, it may not be possible to generalize the results to other connections currently in use. However, although these were external-hex implants, the abutments used did not actually engage the hex. Therefore, it may be possible to generalize the results of this study to other nonengaging abutments currently in use. Regardless, complications noted in this study tended to be fewer than those reported with engaging hexes, commercially pure titanium abutments, and gold screws.[24]

One of the potential criticisms of this study is the point (2.1) that was chosen for the AP spread division. Due to the limited number of patients, dividing them at this point resulted in groups as close to even in number as possible. Three groups—from 1 to 1.5, from 1.5 to 2.0, and greater than 2.0—would have been preferable. This division should be used in a follow-up prospective study. It is possible that previously postulated restrictions in cantilever length and AP spread may not be as critical in patients with a maxillary complete denture and a mandibular MRIFCDP. All patients in this study had a maxillary denture in the opposing arch.

Regarding the details of the complications and their interpretations, if four screws were found to be loose on recall, this was noted as a single complication incident and recorded in the same way as only one screw being loose at a recall appointment. The reason for this decision was that the loosening of one screw can lead to the loosening of other screws. It is impossible to tell precisely why one screw loosened after another or in what order the loosening occurred. Location of the screw complication was not noted, but this would be desirable information in a prospective study. The implant success rate for the subjects in this study was 99.2%. Bone loss was not evaluated relative to cantilever length, posterior spread, and AP spread due to the lack of standardized periapical radiographs in the restrospective study.

An additional limitation of this study was that the number of responses from the treated patients was low. Repeated attempts were made to contact all patients, but those not responding had relocated or changed phone numbers. It should be taken into consideration that the limited sample size might have been the reason that no statistically significant differences were shown between the groups.

Conclusions

Within the limitations of this study, the following conclusions can be drawn:

- Inter- and intrarater measurements were reliable.
- In mandibular MRIFCDPs opposing a maxillary complete denture, no statistical significance was found in predicting whether a screw complication was going to occur relative to age, cantilever length, or AP spread ratio.
- The odds of a screw complication did not increase when the AP spread ratio was less than, equal to, or greater than 2.1, in this same clinical situation.

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Literature Abstract

Mesenchymal stem cells from the oral cavity and their potential value in tissue engineering

Mesenchymal stem cells (MSC) are a unique population of multipotential cells that can differentiate along multiple mesenchymal-derived tissue-specific lineages. Bone marrow has been the major source of MSC for clinical applications. However, harvesting MSC from bone marrow is invasive, carries a risk of infection, and requires ex vivo expansion culturing of the limited number of harvested cells. This article describes sources of MSC from the oral cavity, and discusses their potential regenerative therapy. Sources of oral cavity MSC include dental pulp tissue, exfoliated deciduous teeth, apical papilla of developing teeth, periodontal ligament, and gingival tissue. Oral cavity MSC have similar characteristics as bone marrow MSC: ability to differentiate into osteogenic, chondrogenic, and adipogenic lineages. However, oral cavity MSC are more committed to odontogenic development, and they exhibit potential to differentiate into neurogenic lineages, possibly due to their initial interaction with the neural crest during embryonic development. In addition, oral cavity MSC can differentiate into myocytes, corneal epithelial cells, and melanocytes and even induce pluripotent stem cells. Dental pulp tissue MSC have demonstrated ability to form dentin/pulp-like complexes in mice. Exfoliated deciduous teeth MSC have a higher proliferation rate than other oral cavity MSC and have osteoinductive potential. Apical papilla MSC have the added ability to induce root formation. Periodontal ligament MSC have been shown to regenerate the cementum/periodontal ligament-like complex in vivo. Among all oral cavity MSC sources, gingival tissue has the benefit of being the most accessible, with minimal morbidity due to its rapid healing capacity. The authors concluded that currently the use of oral cavity MSC is still limited to clinical trials. Clinical therapeutic applications can only occur when standardized protocols for safe MSC preparation and transportation are developed.

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