

Three-Dimensional Quantification of the Effects between Different Types of RME

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Abstract

Objectives: To analyse if Hybrid-RME has different effects on skeletal, dental and periodontal aspects when compared with those of Hyrax-RME or Hyrax-SARME.

Methods: In this retrospective multicentre-study 28 patients with a severe nasomaxillary constriction were treated either with a Hyrax-type RME (6 patients, 13.92 ± 0.36 years), with a Hybrid-RME (7 patients, 17.20 ± 2.80 years) or with a surgical assisted Hyrax-SARME (15 patients, 30.58 ± 9.26). This study was performed in analogy to the method published by Garib, et al. using the freeware OsiriX 4.0. All measurements were performed twice with an interval of two weeks and the calculated mean value of both measurements was used for statistical evaluation, which was performed using SPSS 21 for Mac.

Results: The age differences between all groups were significant ($p < 0.001$). All appliances led to a significant skeletal and dental expansion while the buccal bone lamella reduced in dependence of the employed appliance. Effects on the suture were comparable at the canine region while they were significantly different at the molar region, where Hyrax-RME scored first, Hybrid-RME scored second and Hyrax-SARME had the least effects. While Hyrax-RME led to the greatest, Hyrax-SARME showed the least dental expansion at premolar and molar level. Hyrax- and Hybrid-RME showed significantly enhanced skeletal effects on the maxillary base and the skeletal nose than Hyrax-SARME. Hyrax-SARME had significantly less (more than half that much) molar tilting as Hybrid-RME (0.84° vs. 1.74°/ mm activation). Hybrid-RME tended to show the least bone loss (4-12%) while Hyrax-SARME tended to show the most (20-30%).

Conclusions: In patients with a borderline-age (17-20 years) Hybrid-RME might be a promising alternative for Hyrax-RME or Hyrax-SARME to gain skeletal and dental expansion while maintaining the surrounding periodontal bones. Future studies are necessary to investigate if also a surgically assisted Hybrid-SARME might be beneficial in older patients (20+) to combine the parallel dental expansion with the pronounced skeletal effects while maintaining the surrounding bones.

Keywords: Ossification; Hybrid-RME; Hyrax-type RME; Hyrax-SARME

Introduction

Recent studies stated that after a certain point of ossification, conventional dental-borne RME doesn't fulfil the requirements of maximal skeletal and dental effects while sparing the surrounding periodontal tissues at the same time [1]. At this point, supportive surgical weakening (SARME) still provides positive orthodontic and orthopaedic effects and should therefore be applied especially for outgrown adults [1-3]. However there are always patients with borderline-age (in between adolescence and adult maturation) where the practitioner can't be sure if conventional RME might be adequate or a surgical weakening is indicated [4].

The implementation of skeletal anchorage into RME treatment started using the "Dresden-Distractor" [5,6], which reduced the negative side effects associated with tooth-borne RME [6]. The main disadvantage of this appliance was, that beside a mini-screw at one side of the palate, the Dresden-Distractor needed a Straumann-implant (with a diameter of 3.5 mm), which made bone-predrilling sequences necessary [5,6]. Furthermore earlier publications focused on effects in combination with previous surgical weakening [5-11].

Hybrid-RME (also called Hybrid-Hyrax) was implemented to overcome the disadvantage of requiring a 3.5 mm Straumann implant [12]. It just needed two mini-screws placed at the anterior palate [13], whereby the procedure could be performed easily in local anaesthesia [4,14-17]. Previous studies proved that Hybrid-RME has particular

beneficial impact on class III treatment [14,15,17] and furthermore suggested that it might also be a successful alternative to conventional appliances because of its expanding forces at the centre of resistance of the nasomaxillary complex [16-18]. For the practitioner it is of particular interest at what age a specific RME-modification should be preferred, whereby the aim would always be a maximum of therapeutic effectiveness while being minimal invasive.

A study compared skeletal and dental effects of Hyrax-RME and Hybrid-RME in young adults with the same age (13-14 years) [19]. The only significant difference was that the bone thicknesses of the left first premolars significantly differed between groups. Although Hybrid-RME therefore seemed to have advantages over Hyrax-RME, it should be critically questioned if the insertion of mini-implants is justified, considering the fact, that Hyrax-RME was able to lead to a comparable skeletal and dental expansion at that age.

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Because in late adolescents dental RME has its limitations in skeletal expansion [20] and Hyrax-SARME is certainly invasive, it is of particular interest to investigate if Hybrid-RME might still have comparable positive effects at borderline-age.

Therefore, the following questions should be answered in this study:

- Do skeletal, dental and periodontal effects significantly differ between the three approaches of transverse widening?
- Which RME modification achieves the most wanted therapeutic effect?
- Which RME modification caused the worst side effects?
- Does Hybrid-RME or surgical weakening reduce possible side effects?

Materials and Methods

This is a retrospective multi-centre study comprised of 28 patients. All patients had a severe nasomaxillary constriction and were treated either with a Hyrax-type RME (6 patients) or with a Hybrid-RME (7 patients) or with surgical assisted Hyrax-SARME (15 patients) with same appliance design as Figure 1. To achieve maximal therapeutic effects while being minimal invasive, all groups had different average ages. Patients with Hyrax-RME were the youngest (13.92 ± 0.36 years), followed by patients with Hybrid-RME (17.20 ± 2.80 years). Patients who underwent surgical weakening were the oldest (30.58 ± 9.26 years).

One of the investigators (Berna Zorkun, Cumhuriyet University, Sivas, Turkey) performed conventional therapy and one (Wolfgang Kater, Private Practice, Bad Homburg, Germany) performed surgical therapy. 10 patients were men, 18 patients were women. This majority of female gender was present in all subgroups.

Each patient was instructed to activate the Hyrax-screw 3 times a day, so that a daily expansion of 0.60 mm was carried out. The activation amount was carried out according to the individual needs. The RME-appliance remained *in situ* as a retention device for a minimum of three to six months without further activation. In all patients three-dimensional documentation was conducted (low dose CT or CBCT before (T0) vs. after maximal activation (T1)).

This retrospective analysis of the 3D-datasets was reviewed and approved by the ethics commission of the Saarland (Homburg, Germany, Approval number 170/12 from 29.11.2012).

The inclusion criteria of the study are

- No syndromes
- Severe Maxillary transverse deficiency with need for RME or SARME
- Proper 3D-dataset at T0 and T1 (Low-dose CT or CBCT, no artefacts, adequate Field-of-view)
- Successful RME-procedure (mediate Diastema after 5 days)
- Treatment either with Hyrax-RME, Hybrid-RME or Hyrax-SARME

The exclusion criteria include

- Patients with syndromes
- No sufficient 3D-datasets available
- Different radiograph methods between T0 and T1 (Low-dose-CT/CBCT)

This study was performed in analogy to the method published by Garib et al. [21]. All the measurements (points, distances and angles) are explained in Table 1.

As in previous publications for examining the image data the freeware, OsiriX 4.0 (Pixmeo, Bern, Switzerland) was used [21-23]. All measurements were performed twice with an interval of two weeks and the calculated mean value of both measurements was used for statistical evaluation. Statistical analysis was performed using SPSS 21 for Mac. Normal distribution was tested with Shapiro-Wilk test and graphical data output. If normal distribution was given, parametric tests were done. If normal distribution wasn't present, nonparametric tests were performed. Intergroup differences were analysed with Kruskal-Wallis and subsequent Mann-Whitney-U tests. The intraoperator reliability was measured using Spearman Rho and Pearson correlation. For all tests the significance level was set to $p < 0.05$.

Results

Reproducibility

The intraoperator correlation was very high for all measurements. Spearman-Rho tests showed a highly significant correlation for the skeletal distances and dental angles (correlation > 0.99 , $p < 0.001$). Pearson-tests revealed highly significant correlation for the dental distances and periodontal bone changes (correlation > 0.98 , $p < 0.001$).

Patient population and RME-activation

The age differences between all groups were highly significant ($p < 0.001$). The age differences between all groups were significant ($p < 0.001$). Hybrid-RME patients, nonetheless, were significantly older than Hyrax-RME patients ($p < 0.001$).

Overall, no significant differences concerning RME-activation were present between the studied groups ($p = 0.391$). Since the activations were slightly different ($6.26 + -1.89$ mm) and the activation should be ruled out as a potential disruptive factor, all measured values were converted to a change-quotient Δ as recommended by Motro [13] and Bazargani [24].

$$\text{Change-quotient } \Delta = \frac{\text{Measurement T1-T0 (mm)}}{\text{RME-activation (mm)}}$$

This change-quotient Δ is taking into account the patient-dependent individual activation of the expansion screw and therefore describing the treatment effects which result due to 1 mm appliance activation.

Therapeutic effects

All appliances led to a significant skeletal and dental expansion (Table 2) while the employed appliance differently affected the buccal

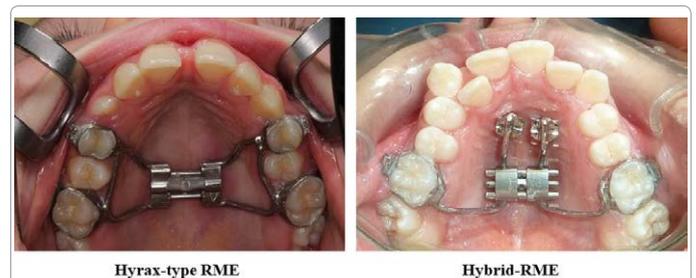


Figure 1: 13 patients received conventional treatment with a Hyrax-RME. 15 additional patients received previous surgical weakening. 7 patients received conventional treatment with Hybrid-RME.

	Type	Definition
Skeletal		
Baseline	Distance	It is defined by the lowest points on both inferior glenoids of the nasal meatus.
Maxillary Base	Distance	It is defined from the transverse extension of the baseline to the right and left maxillary alveolar process.
Suture opening canines	Distance	It describes the width of the midpalatal suture in CT-sectional area at the level of the canines.
Suture opening molars	Distance	It describes the width of the midpalatal suture in CT-sectional area at the level of the upper first molars.
Skeletal nose	Distance	It defines the maximum transverse width of the nasal skeleton at the level of the lower nasal passages. It is parallel to the baseline and is limited by the inside of the bony lateral nasal wall on both sides.
Dental		
Apical distance Premolars	Distance	It describes the distance through the apex centers of the palatal roots of 14 and 24.
Coronal distance Premolars	Distance	It describes the distance through the palatal cusps of 14 and 24.
Apical distance Molars	Distance	It describes the distance through the palatal roots of 16 and 26.
Coronal distance Molars	Distance	It describes the distance through the mesio-palatal cusps of 16 and 26.
Molar Tipping	Angle	This angle defines the inclination of the maxillary first molar's palatal roots to the reference "baseline".
Periodontal		
Bucco-apical bone change 14	Distance	It describes the distance between the center of the buccal root apex of 14 and the alveolar process.
Bucco-apical bone change 24	Distance	It describes the distance between the center of the buccal root apex of 24 and the alveolar process.
Bucco-apical bone change 16	Distance	It describes the distance between the center of the mesiobuccal root apex of 16 and the alveolar process.
Bucco-apical bone change 26	Distance	It describes the distance between the center of the mesiobuccal root apex of 26 and the alveolar process.

Table 1: All measurements were performed in analogy to the study of Garib, et al. [19] and subdivided into skeletal, dental and periodontal effects.

Relative change Δ (effects per mm RME-activation)	Hyrax-RME		Hyrax-SARME		Hybrid-RME		Intergroup differences p-value
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	
Skeletal							
Baseline	0.61	0.14	0.17	0.14	0.44	0.16	0.001
Maxillary Base	0.48	0.18	0.12	0.35	0.34	0.15	0.009
Suture opening canines	0.64	0.32	0.59	0.4	0.54	0.28	0.844
Suture opening molars	1.09	0.35	0.2	0.15	0.44	0.21	0.001
Skeletal nose	0.48	0.17	0.09	0.19	0.47	0.18	0.001
Dental							
Apical distance Premolars	0.86	0.29	0.58	0.43	0.77	0.15	0.099
Coronal distance Premolars	1.34	0.18	1.01	0.51	0.79	0.16	0.006
Apical distance Molars	0.93	0.2	0.44	0.27	0.61	0.2	0.005
Coronal distance Molars	1.4	0.23	0.76	0.39	1.3	0.35	0.003
Molar Tipping	0.98	0.79	0.82	1.04	1.74	0.31	0.053
Periodontal							
Bucco-apical bone change 14	-0.15	0.08	-0.2	0.18	-0.08	0.12	0.598
Bucco-apical bone change 24	-0.17	0.09	-0.21	0.15	-0.04	0.08	0.014
Bucco-apical bone change 16	-0.22	0.33	-0.27	0.22	-0.05	0.06	0.032
Bucco-apical bone change 26	-0.18	0.1	-0.3	0.2	-0.12	0.05	0.033

Table 2: Descriptive statistics and Kruskal-Wallis-Test summarizing the relative changes Δ .

bone lamella. There were significant differences in the effects between all three appliances.

Skeletal Effects

RME-treatment in all three study groups led to a significant widening of the baseline. Hyrax-RME and Hybrid-RME showed significantly larger effects on the baseline than SARME treatment ($p < 0.05$) (Figure 2).

Hyrax-RME achieved the greatest effect on the maxillary base, Hybrid-RME placed second while SARME had the least impact ($p < 0.006$) (Figure 3). Both Hyrax-RME and Hybrid-RME led to a significantly higher widening of the skeletal nose ($p = 0.001$). There was no significant difference between both conventional appliances in regard to their effects on the skeletal nose ($p = 0.945$) (Figure 4).

All appliances led to a comparable widening of the maxillary suture at the canine level. There was no significant difference between them

($p > 0.67$) (Figure 5). However significant differences were detected at concerning suture opening at molar level: while Hyrax-RME had the significantly strongest effects ($p < 0.01$), Hybrid-RME had less powerful effects. Still Hybrid-RME was significantly stronger than Hyrax-SARME ($p = 0.009$) (Figure 6).

Dental Effects

All three appliances led to a comparable apical dental expansion at the premolar area. There was no statistical significant difference ($p > 0.1$). Hyrax-RME led to a higher dental expansion at the coronal premolar area than both other appliances ($p < 0.012$) (Figure 7). There was no statistical significant difference between Hybrid-RME and Hyrax-SARME ($p = 0.237$).

Both Hyrax-SARME and Hybrid-RME led to a significant minor transverse apical expansion in the molar region ($p = 0.022$). There was no statistical significant difference between Hybrid-RME and Hyrax-

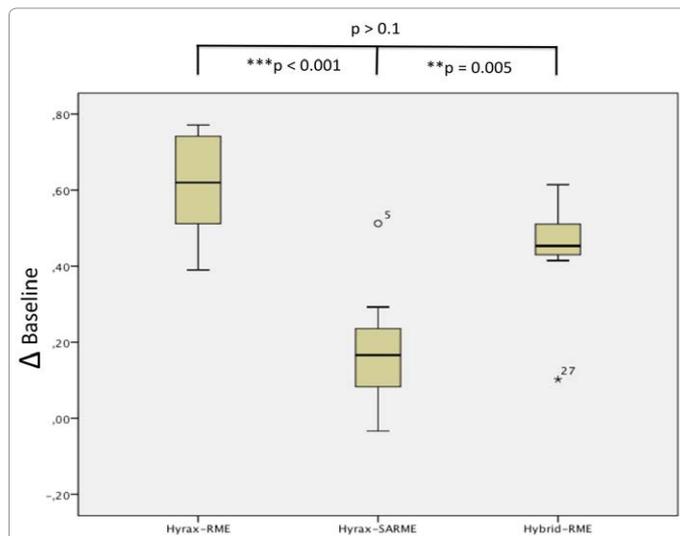


Figure 2: Hyrax-RME and Hybrid-RME showed significantly larger effects on the baseline than Hyrax-SARME treatment.

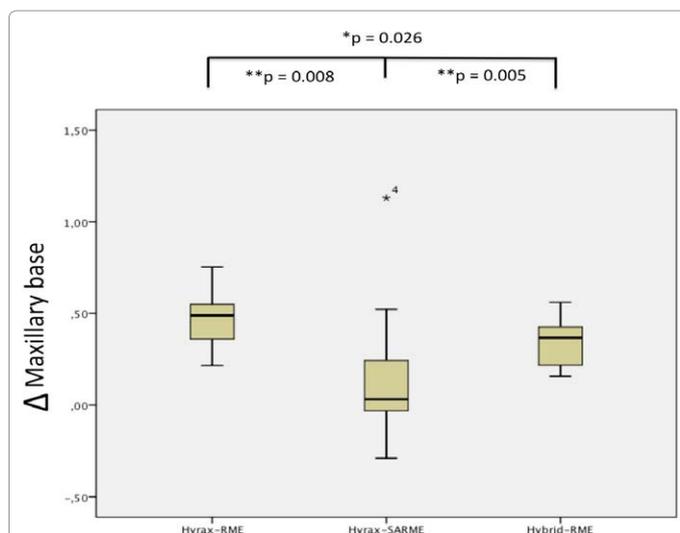


Figure 3: Hyrax-RME achieved the greatest effect on the maxillary base, Hybrid-RME placed second while Hyrax-SARME had the least impact.

SARME. Hyrax-RME and Hybrid-RME led to a significantly higher expansion at the coronal molar level than Hyrax-SARME ($p < 0.005$). There was no significant difference between Hybrid-RME and Hyrax-RME. Hybrid-RME showed the highest tipping effects at the first upper molar area (Figure 8). This was significant in comparison to Hyrax-SARME ($p = 0.026$). There was no significant difference between Hyrax-RME and Hyrax-SARME ($p = 0.733$).

Periodontal Effects

Hybrid-RME tended to spare the buccal bone lamella. While there was no statistical significant difference at 14 ($p > 0.366$), it was significant at 24 ($p < 0.022$) (Figure 9). Furthermore Hybrid-RME showed less buccal bone loss in the apical area of 16 and 26 than both other appliances (Figures 10). This difference was highly significant in comparison to Hyrax-SARME ($p = 0.017$) but not in comparison to Hyrax-RME ($p > 0.101$).

Discussion

For our study, we used OsiriX software as it was suggested in

comparable publications [21-23]. Due to the retrospective design of this study both low-dose CT and CBCT were analysed because both methods proved to be accurate for 3D-measurements [25]. Additionally for precision, only those patients were included with the same type of radiograph method at T0 and T1.

All measurements, which were adopted and modified according to Garib et al. [21], showed very high reproducibility which is consistent with the literature [26]. Although there were no significant differences concerning the activations between all three types of RME, we analysed the relative changes as recommended by Motro [13] and Bazargani [24] to enhance the comparability even further. This statistical accuracy was not taken into account in earlier studies [1,26,27] and might therefore be a reason for possible errors of previous publications.

Our results suggest that Hyrax-RME had the strongest expansive effects when applied at premature age. For every 1 mm activation, it led to a skeletal enlargement between 48 and 109%, while at the dental level it

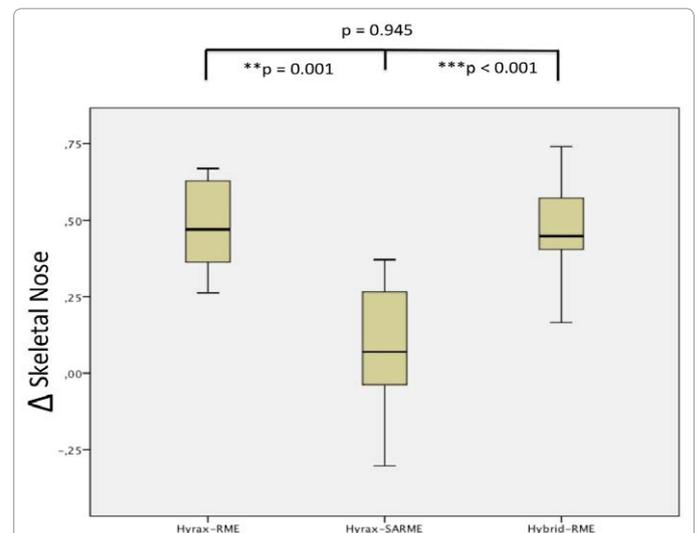


Figure 4: Both Hyrax-RME and Hybrid-RME led to a significantly higher widening of the skeletal nose.

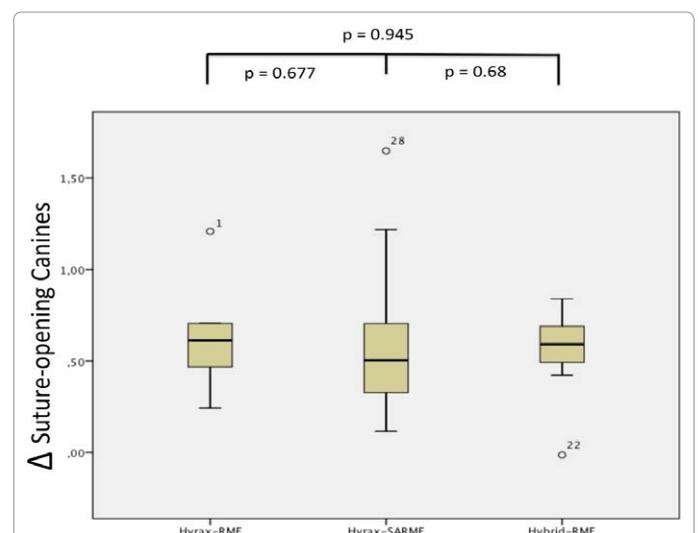


Figure 5: All appliances led to a comparable widening of the maxillary suture at the canine level.

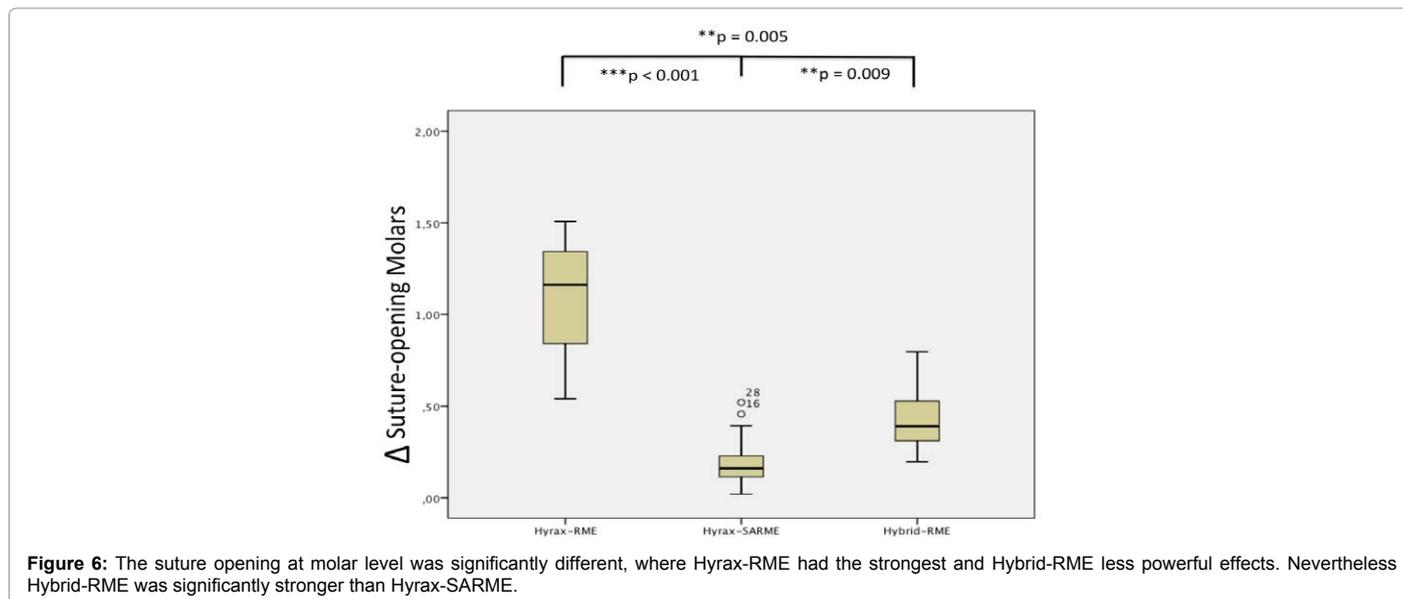


Figure 6: The suture opening at molar level was significantly different, where Hyrax-RME had the strongest and Hybrid-RME less powerful effects. Nevertheless Hybrid-RME was significantly stronger than Hyrax-SARME.

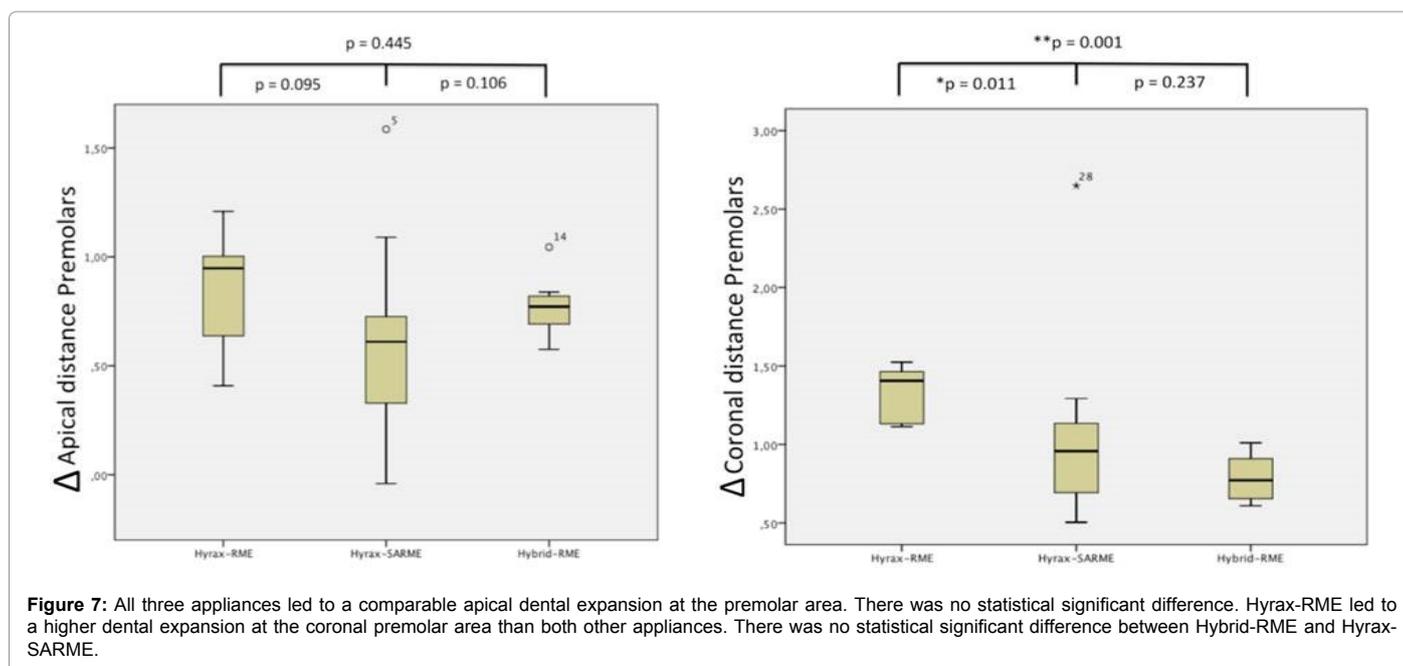


Figure 7: All three appliances led to a comparable apical dental expansion at the premolar area. There was no statistical significant difference. Hyrax-RME led to a higher dental expansion at the coronal premolar area than both other appliances. There was no statistical significant difference between Hybrid-RME and Hyrax-SARME.

resulted in an expansion between 86 and 140% with a pronounced level of tilting at the premolar area and an average tilting at the molar level.

In our study Hybrid-RME patients had a borderline-age (17.20 ± 2.80 years). Nevertheless our treatments led to a significant skeletal ($\Delta=34-54\%$) and dental expansion ($\Delta=61-130\%$), whereby Hyrax-SARME and Hybrid-RME patients showed a V-shaped opening pattern with larger skeletal effects in the canine area ($\Delta=54-59\%$) and less skeletal effects in the molar area ($\Delta=20-44\%$). In Hyrax-RME patients this situation reversed.

Hyrax-SARME and Hybrid-RME patients showed an opening of the midpalatal suture between ($\Delta=$) 20% and 59%, what stays in accordance with a current review of Bazargani et al., who found a mean sutural expansion between ($\Delta=$) 22%-53% with a large variation in the opening pattern [24]. The highly significant ($p<0.006$) stronger

effects of Hyrax-RME at the posterior suture might be explained due to the significant younger age in that group and the hereby decreased ossification level [28].

Furthermore Hybrid-RME showed the least tilting in the premolar and the highest tilting in the molar area. This can be explained with the appliance depended missing of dental anchorage in the premolar area [12] and the direct transmission of force at the centre of resistance of the nasomaxillary complex [16]. Nonetheless Hybrid-RME showed more than twice as powerful skeletal effects ($\Delta=44\%$) at the premolar area than Hyrax-SARME ($\Delta=20\%$).

It is said that the rate of expansion and retention time doesn't have significant association to buccal bone losses after SARME [26]. In accordance with this we could show that there was no significant correlation between the rate of expansion and bone losses. However

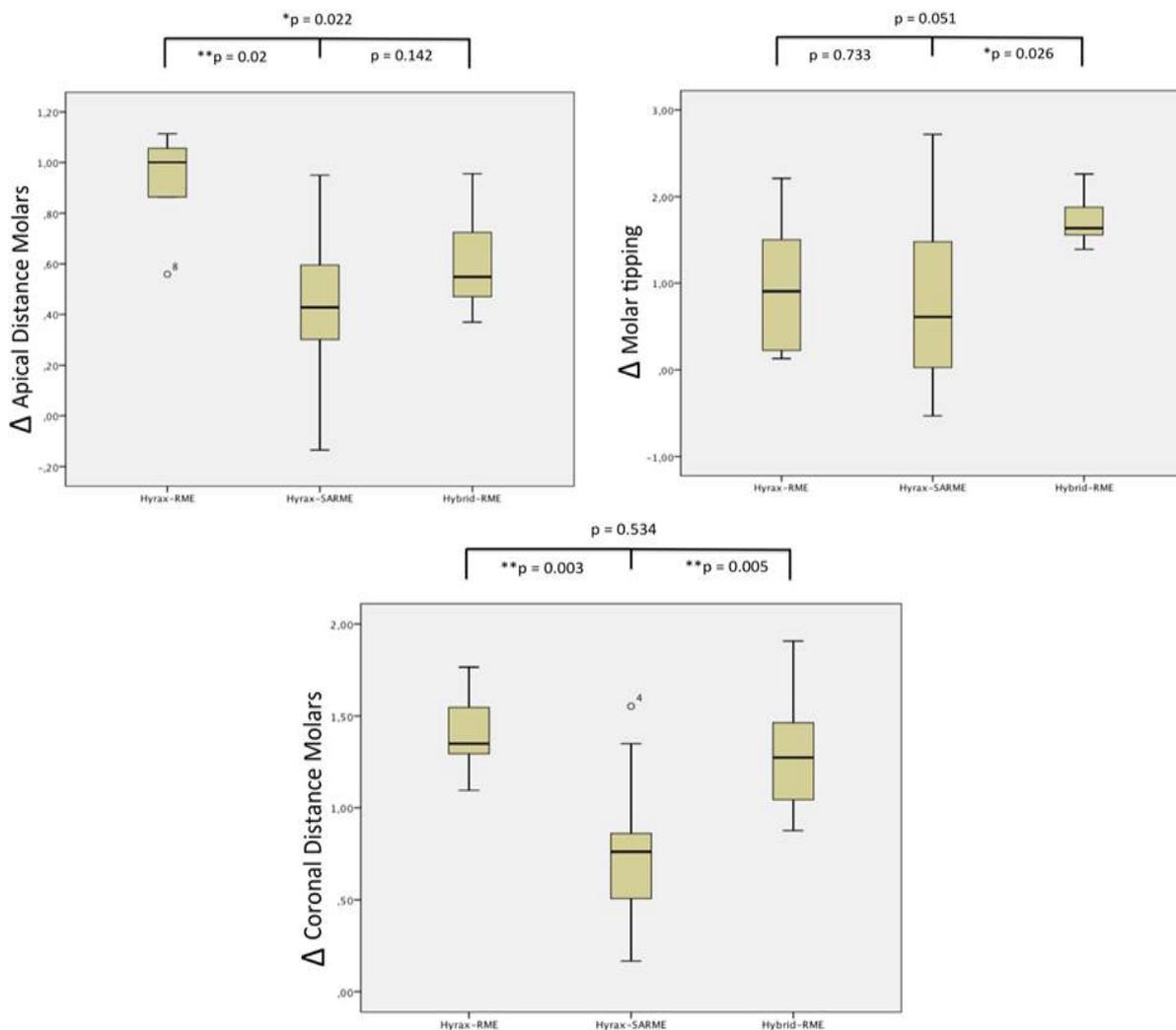


Figure 8: Both Hyrax-SARME and Hybrid-RME led to a significant minor transverse apical expansion in the molar region. Hyrax-RME and Hybrid-RME led to a significantly higher expansion at the coronal molar level than Hyrax-SARME. Hybrid-RME showed the highest tipping effects at the first upper molar area.

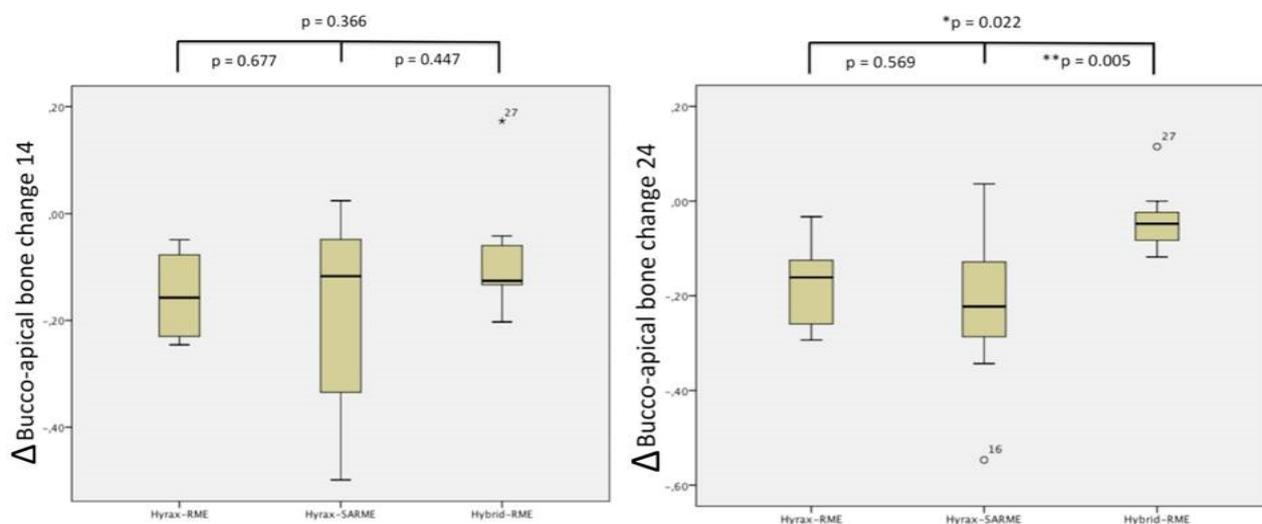


Figure 9: Hybrid-RME tended to spare the buccal bone lamella. While there was no statistical significant difference at 14 it was significant at 24.

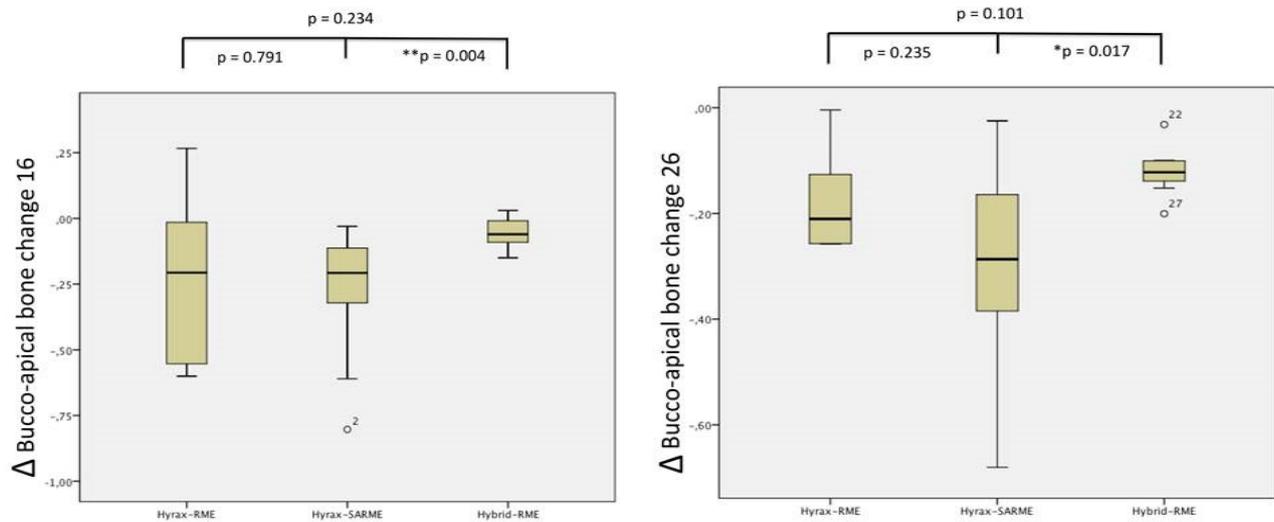


Figure 10: Hybrid-RME showed less buccal bone loss in the apical area of 16 and 26 than both other appliances, whereby this difference was even significant in comparison to Hyrax-SARME.

the clinical conclusion of a recently published study, stating that “SARME does not affect the health status of the periodontal tissues” should subsequently be critically discussed [27].

Our results suggest that, no matter what appliance investigated, buccal bone loss occurred, which was overall between (Δ =) 4-30%. However Hybrid-RME tended to prevent these negative side effects both for premolar and molar region with the smallest mean losses (which were between 4 and 12%) and these trends were even partially significant in comparison to both other appliances. While Hyrax-RME scored an average result (Δ =) 15-22% in all four analysed areas, Hyrax-SARME showed pronounced buccal bone resorption of (Δ =) 20-30%. Bone loss leads to a deterioration of the periodontal situation. In consequence there are plenty of studies in Periodontology and Implantology dealing with approaches to improve bone sparing [29,30]. Our results lead to the conclusion that Hybrid-RME was able to achieve a significant skeletal and dental expansion while stressing the surrounding bones the least at the same time, even though it was applied in borderline-age patients.

Laudemann et al. showed that surgically assisted dental borne devices tended to show an increase in transverse widening but at the price of greater attachment loss [31]. Our study leads to the supposition, that also in surgical cases the implementation of mini-screws (Hybrid-SARME) could help to prevent attachment losses, as Hybrid-RME does in conventional cases. Further studies are necessary to prove this hypothesis.

Conclusions

With the results of our study we can conclude that both Hyrax and Hybrid-RME showed significantly stronger skeletal effects on the maxillary base and the skeletal nose than Hyrax-SARME. Hyrax-SARME had significantly less molar tilting effects as Hybrid-RME (Δ = 0.84° vs. Δ = 1.74°). Hybrid-RME tended to show the least bone losses (Δ = 4-12%) while Hyrax-SARME tended to show the most (Δ = 20-30%). In young adolescents Hyrax-RME seems to be adequate, in patients with borderline-age (17-20 years) Hybrid-RME might have certain advantages and in older adults (20+) surgical weakening seems to be justified.

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