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Influence of the orthognathic surgical procedure Le Fort I osteotomy on the vascularity and neurosensory response of the dental pulp: A systematic review

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Objective: Abnormalities of the midface and maxilla are frequently corrected using Le Fort I surgery. This osteotomy passes near the apices of the maxillary teeth, severing the blood vessels and nerves supplying the teeth. The aim of this review was to determine the effect of Le Fort I osteotomy on pulpal vascularity and neurosensory response. **Data Sources:** A systematic search of the literature was performed in PubMed/Medline, Google Scholar, EMBASE, and ISI Web of Knowledge from 1969 up to and including December 2015 using the following key words: Le Fort 1, tooth vitality, maxillary osteotomy, pulp, orthognathic. Reference lists of relevant articles were hand-searched for additional articles. **Results:** Sixty-two studies were located by initial screening; 38 did not meet the eligibility criteria; three were excluded after full-text review, 13

were excluded after quality assessment, leaving nine studies eligible that met all inclusion criteria for this systematic review. The postoperative follow-up period of the included studies ranged from 3 months to 28 months. Five studies assessed pulpal blood flow using laser Doppler flowmetry and eight studies assessed the pulpal neurosensory response using electric pulp testing. **Conclusion:** There is a decrease in pulpal vascularity and neurosensory response following a Le Fort I osteotomy in the early postoperative period (1 to 10 days) that is likely temporary. Further controlled clinical studies with standardized parameters are required to determine the long-term effects of Le Fort I osteotomy on the vascular and neural healing of the dental pulp. (doi: 10.3290/j.qi.a36386)

Key words: Le Fort I osteotomy, pulpal neurosensory response, pulpal vascularity

Orthognathic surgery is the skeletal movement of jaw bones for correcting dentofacial discrepancies through procedures such as mandibular split osteotomies, segmental alveolar osteotomies, and the Le Fort I (LFI)

maxillary osteotomy.¹ The LFI is a versatile surgical technique used to correct transverse, vertical, and sagittal maxillary discrepancies.² This osteotomy approach also provides access for extirpation of tumors involving the central skull base.³ The LFI surgical technique involves division of the nasopalatine nerve, and the anterior, middle, and posterior superior alveolar nerves, which supply the teeth and periodontal structures. It is likely that iatrogenic vascular and neurosensory damage may occur during LFI osteotomy. Intraoperative mobilization of the maxillary segment could damage the greater palatine nerves or they may be divided to

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enable greater movement.⁴ This disruption of blood and neural supply may cause complications in the maxillary segment,⁵ ranging from periodontal defects, degenerative damage to the pulp, irreversible loss of pulp vitality, non-union of the repositioned segment, and, in extreme cases, avascular necrosis of the maxilla.⁶⁻⁸ Dentists treating patients that have undergone the LFI orthognathic surgical technique should be aware of the altered sensory function and vitality of the involved teeth.

Thygesen et al⁹ observed that the highest complication rates following LFI osteotomies were reported in studies concerning pulp vitality. Biologic variations such as age and sex may predispose to these complications.¹⁰ Multiple other pre- and postoperative factors may affect pulp sensibility following LFI osteotomy. For instance, patients undergoing planned osteotomies for correction of dentoskeletal discrepancies conventionally receive pre- and postoperative orthodontic treatment, which may jeopardize tooth vitality.¹¹ Another factor that may affect pulp vitality is the proximity of the root apex to the level of the horizontal osteotomy.¹²⁻¹⁴ It has been reported that the teeth adjacent to vertical osteotomy sites may experience temporary loss of sensory nerves.¹⁵ Similarly, segmentation of the maxilla and level of the osteotomy line have been suggested to affect the postoperative changes in sensitivity from 9% to 85%.^{16,17} Additionally, hypotensive anesthesia is recommended to control intraoperative blood loss during orthognathic surgery.^{18,19} The decreased intraoperative maxillary blood from the hypotensive anesthesia may affect pulpal blood flow (PBF).²⁰ Therefore, from a clinical perspective, it is hypothesized that LFI osteotomy jeopardizes the pulp vitality of maxillary teeth.

In a study to evaluate the recovery of tooth sensibility after LFI osteotomy, Kahnberg and Engstrom²¹ reported that almost all teeth did not respond to electric stimulation 2 months postoperatively; but at 18 months postoperatively 90% to 100% of teeth changed to a positive response. Justus et al²² observed an increased PBF in patients undergoing LFI osteotomies 1 to 3 weeks postoperatively and contended that this

was due to the healing process. In a study on the longitudinal changes in PBF after LFI osteotomy, Eroglu and Sabuncuoglu²³ reported a decrease in PBF in all tooth types over a 12-month period. Thus, there appears to be no consensus among different studies on the effects of LFI surgery on pulpal response.

To our knowledge from indexed literature, there are no studies that have systematically reviewed the influence of LFI osteotomy on the vascularity and neurosensory response of the dental pulp. Therefore, the aim of the present study was to systematically review the influence of LFI osteotomy on pulp vascularity and neurosensory response.

DATA SOURCES

Eligibility criteria

The inclusion criteria were as follows:

- original studies
- clinical studies
- case series
- studies in which LFI osteotomy was performed
- studies that used laser Doppler flowmetry (LDF) or the electric pulp test (EPT) to assess pulpal vascularity and neurosensory response
- studies with a quality assessment score of 8 or higher.

Studies in which segmental maxillary osteotomies were performed, animal studies, case reports, commentaries, review articles, letters to the editor, and unpublished articles were excluded.

Information sources, search strategy, and study selection

The current Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist was used to conduct the search.²⁴ The international database of Prospectively Registered Systematic Reviews in Health and Social Care (PROSPERO) and the Cochrane Register of Systematic Reviews were searched in December 2015 and showed no existing or current review protocols assessing the effect of LFI osteotomy on the dental pulp. PubMed/Medline (National Library



Table 1 Quality assessment of included studies

Study	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Item 12	Total quality score (0 to 12)
Kahnberg et al ²¹	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	9
Vedtofte ²⁵	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	8
Vedtofte et al ²⁶	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	8
Aanderud et al ²⁷	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Cannot tell	Yes	8
Sato et al ³¹	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	9
Hadara et al ³²	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Cannot tell	Yes	8
Hadara et al ³³	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	9
Thygesen et al ⁹	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Cannot tell	Yes	10
Eroglu et al ²³	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Cannot tell	Yes	10

of Medicine), Google Scholar, EMBASE, and ISI Web of Knowledge databases were searched from 1969 up to and including December 2015 using different combinations of the following terms: Le Fort I, tooth vitality, maxillary osteotomy, pulp, orthognathic.

Titles and abstracts of studies that fulfilled the eligibility criteria were individually assessed by two authors. Articles whose abstracts were not available or did not provide adequate information were assessed in full text. Full texts of the relevant studies were read by the authors and assessed with reference to the selection criteria. Any disagreement was resolved by discussion. As a next step, reference lists of original and review studies were manually searched to identify any articles that could have been missed during the initial search.

RESOURCE SELECTION

Data were collected using a customized data extraction form based on the Data Extraction Template for Cochrane. The primary outcome measurement was PBF and neural response of the pulp following LFI osteotomy. The primary predictor variables recorded were patient age, sex, and specific information on the type of LFI osteotomy. Information on study design, method of assessment of pulp vitality, use of splints for accurate recording of blood flow, orthodontic treatment, and follow-up period was recorded.

Quality assessment of the studies

Table 1 presents the quality assessment of studies that were included, performed in an attempt to increase the strength of the present systematic review. The 22 studies^{3,4,9,10,12-14,20-23,25-35} that were included underwent a quality assessment with the Critical Appraisal Skills Program (CASP) Cohort Study Checklist. The CASP tool uses a systematic approach based on 12 specific criteria, which are:

- Study issue is clearly focused
- Patients are recruited in an acceptable way
- Exposure (LFI osteotomy) is accurately measured
- Outcome (PBF and/or neurosensory reaction) is accurately measured
- Confounding factors are addressed
- Follow-up is long and complete
- Results are clear
- Results are precise
- Results are credible
- Results can be applied to the local population
- Results fit with available evidence
- There are important clinical implications.

Each criterion was given a response of either “yes”, “no”, or “cannot tell”. Each study could have a maximum score of 12. CASP scores were used to grade the methodologic quality of each study assessed in the present systematic review.

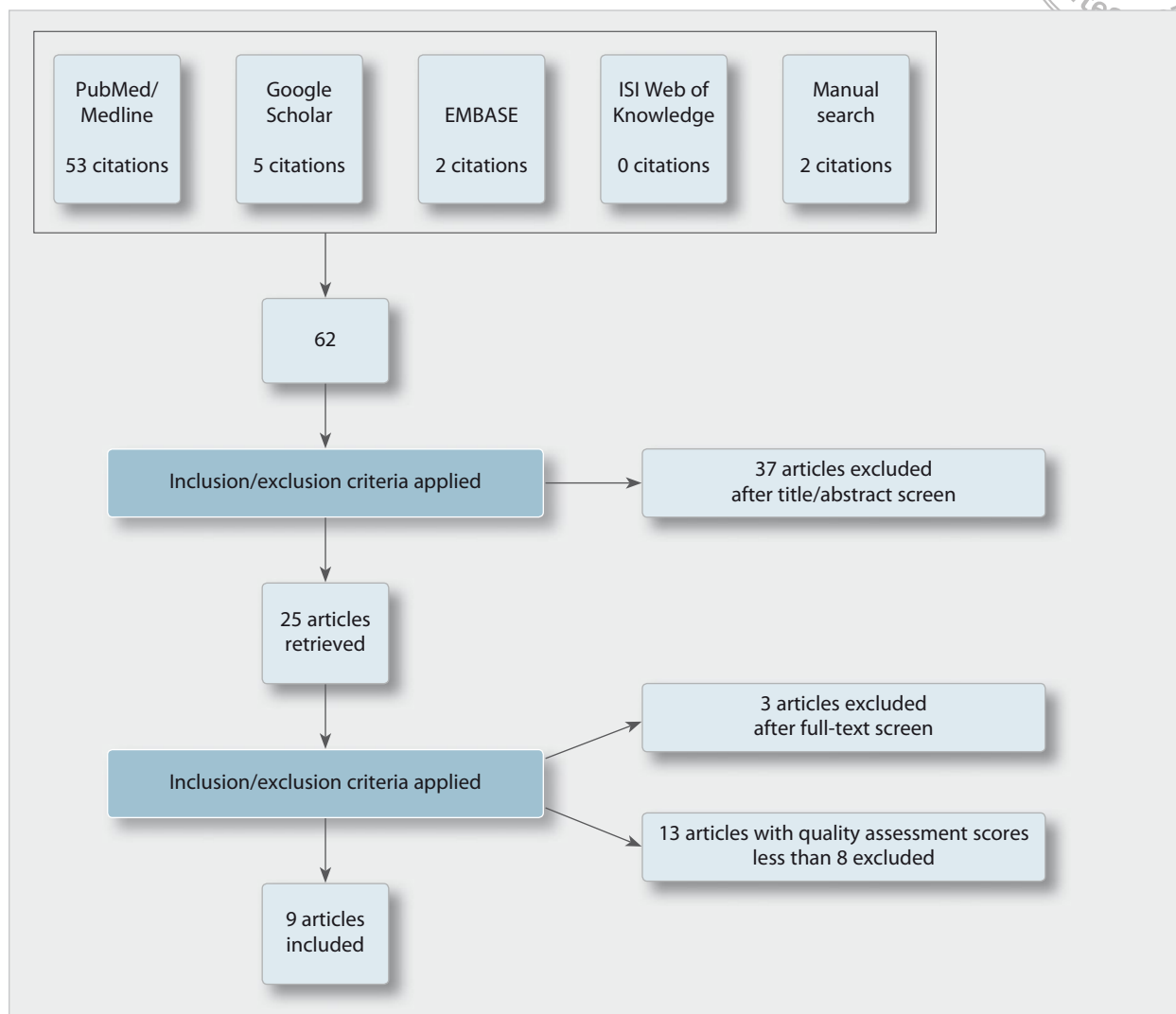


Fig 1 Article selection flow chart for the systematic review according to PRISMA guidelines.

REVIEW

The initial search yielded 62 studies (Fig 1). Forty studies that did not fulfill the eligibility criteria were excluded (see supplementary Appendix 1, available in the online version at <http://quintessenz.de>). To differentiate the high-quality papers from the low-quality ones and give the high-quality studies more weight in the outcome analysis, 13 studies^{3,4,10,12-14,20,22,28-30,34,35} with a CASP score of less than 8 were excluded. In total, 9 studies^{9,21,23,25-27,31-33} were included and processed for data extraction. Figure 1 illustrates the PRISMA flowchart of this process.

Quality assessment of the studies

Quality scores of the studies^{3,4,9,10,12-14,20-23,25-35} ranged from 6 to 10. Studies^{3,4,10,12-14,20,22,28-30,34,35} with CASP quality scores below 8 were excluded from the analysis as they might have diminished the validity of the review conclusions. Quality assessment of the remaining studies^{9,21,23,25-27,31-33} showed that, in general, recruitment of the patients and the surgical intervention (LFI osteotomy) were adequately performed in these studies (Table 1). As only studies in human subjects were included, the results could be considered to be applicable to the local population. With reference to recruit-



Table 2 Design, interventions, and outcome measures of included studies

Study	Study design	Participants		Intervention	Comparator	
		Participants, n (male)	Age, mean (range)	Surgery	Control	Outcome
Kahnberg et al ²¹	CT	Surgery 30 (NA)	Surgery 21.4 (NA)	30 LFI *	NA	PNR
Vedtofte ²⁵	CT	Surgery 51 (16)	Surgery 24 (15–46)	51 LFI	NA	PNR
Vedtofte et al ²⁶	CT	Surgery 51 (16)	Surgery 24 (15–46)	51 LFI	NA	PNR
Aanderud et al ²⁷	CCS	Surgery 15 (5)	Surgery 28.5 (21–41)	15 LFI	14	PBF, PNR
		Control 14 (5)	Controls 26 (19–42)			
Sato et al ³¹	CT	Surgery 14 (5)	Surgery 22.8 (19–28)	14 LFI*	NA	PBF, PNR
Hadara et al ³²	CT	Surgery** 5 (1)	Surgery 18 (13–23)	5 LFI†	NA	PBF, PNR
		Surgery* 14 (5)	Control 22.8 (19–28)	14 LFI*		
Hadara et al ³³	CT	Surgery# 9 (3)	Surgery 24.6 (19–31)	9 LFI‡	NA	PBF, PNR
		Surgery* 14 (5)	Control 22.8 (19–28)	14 LFI*		
Thygesen et al ⁹	CT	Surgery 25 (12)	Surgery NA (15–35)	23 LFI	NA	PNR
Eroglu et al ²³		Surgery 21 (NA)	Surgery 19.7 (8–25)	14 LFI	7	PBF

*Downfracture.

†Maxillary distraction.

‡Horseshoe osteotomy.

CCS, case controlled study; CT, clinical trial; PBF, pulpal blood flow; PNR, pulpal neural response; LFI, Le Fort I osteotomy; NA, not available

ment of patients, only two studies^{9,23} reported approval from a review board. A common shortcoming was that confounding factors were not addressed in the included studies. This contributed to the difficulty in determining whether the results were in accordance with the available evidence.

Study characteristics

Nine studies^{9,21,23,25-27,31-33} reported the influence of LFI osteotomy on pulp vitality, as presented in Table 2. The age of the study participants ranged between 8 and 46 years. Two studies^{32,33} had a case control design. Six studies^{9,23,27,31-33} reported that participants received orthodontic treatment in conjunction with LFI osteotomy. Of these, two studies^{23,27} reported that orthodontic treatment was provided only to participants undergoing surgery, and not the controls. The distance of horizontal osteotomy from apices of teeth was reported in three studies.^{23,25,26} Three studies^{21,25,26} tested all teeth; two studies^{23,27} tested a combination of incisors, canines, and first premolars; one study³⁴ tested canines only and three studies³¹⁻³³ tested incisors only for vitality.

Pulp vitality was assessed using the EPT in eight studies,^{9,21,25-27,31-33} and LDF was used to assess pulp vitality in five studies.^{23,27,31-33} Initial readings of pulp vitality were measured preoperatively in six studies.^{9,21,23,31-33} In two studies,^{25,26} initial readings of pulp vitality were measured postoperatively. The duration of final measurements of pulp vitality ranged from 3 months to 28 months postoperatively.

Outcome of studies assessing pulpal neurosensory response using EPT

EPT readings in studies which tested pulp vitality in all teeth

Three studies^{21,25,26} measured pulp vitality in all teeth. In three studies,^{21,25,26} the percentage of teeth that responded negatively to EPT at the final postoperative follow up ranged from 0% to 15%. The duration of the final postoperative follow-up ranged from 18 to 28 months in these studies.

EPT readings according to the tooth class

- **Incisors:** Five studies^{21,26,31-33} reported EPT readings for incisors. The duration of the final postoperative



Table 3 Results of studies assessing vitality by laser Doppler flowmetry

Authors	Teeth measured	Preoperative assessment	First postoperative assessment		Final postoperative assessment		Nonvital teeth at final follow-up	Use of custom-made splint
		Surgical group	Time (days)	Surgical group	Time (days)	Surgical group		
Aanderud et al ²⁷	Incisors					00		
	Canines	NA	NA	NA	510 (330–870)	00	1/117	Yes
	1st premolars					++		
Sato et al ³¹	Incisors	NA	1–7	–	365	–	Zero	Yes
Hadara et al ³²	Incisors	NA	1–7	–	90	–	Zero	Yes
Hadara et al ³³	Incisors	NA	1–7	–	365	–	Zero	Yes
Eroglu et al ²³	Incisors, canines, 1st premolars	00	7	–, ––	365	–, ––	Zero	Yes

+, Significant increase in blood flow compared to controls.
 0, No significant change in blood flow compared to control.
 –, Significant decrease in blood flow compared to presurgical values.
 ––, Significant decrease in blood flow compared to controls.

follow-up for these studies ranged from 3 months to 59 months. The percentage of central incisors that responded negatively to EPT at the final postoperative follow-up ranged from 0% to 71%. The percentage of lateral incisors that responded negatively to EPT at the final postoperative follow-up ranged from 0% to 3%.

- **Canines:** Two studies^{21,26} reported EPT readings for canines. The duration of the final postoperative follow-up for these studies ranged from 18 months to 59 months. The percentage of canines that responded negatively to EPT at the final postoperative follow-up ranged from 0% to 19%.
- **Premolars:** Two studies^{21,26} reported EPT readings for premolars. The duration of the final postoperative follow-up for these studies ranged from 18 months to 59 months. The percentage of premolars that responded negatively to EPT at the final postoperative follow-up ranged from 0% to 4%.
- **Molars:** Two studies^{21,26} reported EPT readings for molars. The duration of the final postoperative follow-up for these studies ranged from 18 months to 59 months. The percentage of molars that responded negatively to EPT at the final postoperative follow-up ranged from 5% to 15%.

Outcome of studies assessing pulpal blood flow using LDF

Five studies^{23,27,31–33} used custom-made acrylic splints for accurate repositioning of the LDF probe on the teeth at follow-up (Table 3). Four studies^{23,31–33} reported that there were no nonvital teeth detected by LDF at the final follow-up. Aanderud-Larsen²⁷ reported one nonvital tooth by LDF in their series of 117 teeth examined.

LDF results according to the tooth class

- **Incisors:** Five studies^{23,27,31–33} measured pulp vitality of incisors using LDF. At the preoperative assessment, Eroglu and Sabuncuoglu²³ reported no significant change in incisor blood flow compared to controls. The mean duration of the final postoperative follow-up for these studies ranged from 3 months to 17 months. Four studies^{23,31–33} reported a significant decrease in incisor blood flow compared to presurgical values at the final postoperative follow-up. One study²³ reported a significant decrease in incisor blood flow compared to controls at the final postoperative follow-up. One study²⁷ reported no significant change in incisor blood flow compared to controls at the final postoperative follow-up.

- **Canines:** Two studies^{23,27} measured pulp vitality of canines using LDF. At the preoperative assessment, Eroglu and Sabuncuoglu²³ reported no significant change in canine blood flow compared to controls. The mean duration of the final postoperative follow-up for these studies ranged from 12 months to 17 months. Eroglu and Sabuncuoglu²³ reported a significant decrease in canine blood flow compared to both presurgical values and controls at the final postoperative follow-up. One study²⁷ reported no significant change in canine blood flow compared to controls at the final postoperative follow-up.
- **Premolars:** Two studies^{23,27} measured pulp vitality of premolars using LDF. At the preoperative assessment, Eroglu and Sabuncuoglu²³ reported no significant change in first premolar blood flow compared to controls. The mean duration of the final postoperative follow-up for these studies ranged from 2 months to 17 months. Eroglu and Sabuncuoglu²³ reported a significant decrease in first premolar blood flow compared to both presurgical values and controls at the final postoperative follow-up. Aanderud-Larsen et al²⁷ reported a significant increase in first premolar blood flow compared to controls at the final postoperative follow-up.

DISCUSSION

Summary of evidence

To the present authors' knowledge, this is the first systematic review that assesses the influence of LFI osteotomy on pulpal vascularity and neurosensory response. Nearly half of the included studies^{23,27,31-33} used the LDF to evaluate PBF. The majority of the studies^{23,31-33} reported a decrease in PBF. It is pertinent to mention a tooth-type-specific effect of LFI on pulpal responsiveness. Eighty percent of the studies^{23,25-27} that tested different classes of teeth reported that the canine and premolar teeth had the greatest variability in recovery of pulpal response. This could be explained by considering the proximity of these teeth to the vertical interdental osteotomy in segmental osteotomies, as well as the closeness of their root apices to the horizontal

osteotomy line. The distance of the horizontal osteotomy from the root apex is crucial for pulp survival.³⁶ Since the canine and premolar teeth have longer roots, it is plausible that the blood supply to these teeth may be affected more than the other classes of teeth.

Compared to other methods of testing pulpal vitality, LDF is credited with having greater accuracy.^{37,38} Ikawa et al³⁹ showed that the resting PBF as well as stimulated PBF significantly decrease with advancing age. In most studies,^{4,10,13,23,25-34} patients were young, viz. in their third decade of life. Considering the atherosclerotic changes and the decreased number of pulpal blood vessels with progressing age,³⁹ the reliability of these results in older individuals is questionable. However, the validity of LDF measurements, particularly in elderly subjects, who have smaller pulp chambers with lower PBF values, requires further investigation.⁴⁰

Variability in the surgical technique may have also affected the pulpal response. For example, two studies^{27,33} assessed incisor blood flow; Aanderud-Larsen et al²⁷ reported performing a LFI osteotomy with accompanying mandibular procedures, while Harada et al³³ reported data from patients receiving a combined LFI and horseshoe osteotomy. In this technique, the denotoalveolar segment of the maxilla is preferentially mobilized, keeping the palatal segment with the descending palatal artery intact, in an attempt to maintain the perfusion of the maxilla. In spite of this, Harada et al³³ observed a decrease in final postsurgical PBF.

Considering that in the series by Aanderud et al,²⁷ a mandibular osteotomy was performed concurrently in patients undergoing a LFI surgery, the postsurgical increased PBF is remarkable. It would be expected that the "stealing of dental pulp perfusion pressure"^{23,40} by the mandibular osteotomized segment might have decreased pulpal perfusion postoperatively. This effect suggests that rerouting of the blood flow due to either stretching of the descending palatine artery or redirection of blood flow to localized facial swelling (the mandibular osteotomy in this case) might cause reduced perfusion of the maxillary segment postoperatively.²³

Similarly, the effect of intraoperative blood loss on pulpal perfusion must be considered. Only one study²⁷



mentioned intraoperative blood loss. It has been reported that there is a significantly greater blood loss in patients undergoing LFI surgery compared to patients undergoing mandibular osteotomies.²² It is hypothesized that PBF may be reduced following LFI osteotomy due to this greater intraoperative blood loss. Interestingly, in the study²⁷ recording intraoperative blood loss, no change in the PBF in incisors and canines and an increase in PBF in premolars compared to controls was reported. It is likely that there are other factors, such as volume of blood lost or any coexisting systemic illness, that might influence the postoperative PBF, and further studies will be required to determine the effects of intraoperative blood loss on PBF.

Variations also existed in the pre- and postoperative measurements of pulp vitality and neurosensory response. The time of final assessment of pulp response varied from 3 months to 28 months. It would be interesting to know what criteria were used when determining the follow-up time. Perhaps studies^{13,20,30,32,34} with a shorter follow-up expected postoperative acute inflammation to affect PBF and the neural response, pulp sensitivity. It is surmised that they expected a period of ischemia, attributable to orthodontic treatment or hypotensive anesthesia or blood loss, and expected this to resolve in the initial postoperative period. It is tempting to speculate that studies^{3,21,25,26,28,29,35} with a longer follow-up were more concerned with the effects of the trauma of the osteotomy on the maxillary neural supply and perfusion. Nearly half of the studies^{23,27,31-33} showed that the PBF decreased significantly 1 to 10 days postoperatively, compared to preoperative values. This reduction persisted until the final follow-up. Contrasting these findings with the study²⁷ with the longest final follow-up period (11 to 29 months), it is speculated that this decreased PBF could be the postoperative effect of the osteotomy, and that, with time, the blood flow may return to baseline values.

Standardization in the surgical protocols may be helpful when investigating the effects of LFI osteotomy on pulp vitality. The literature reports a variety of surgical modifications to the conventional LFI osteotomy for

correcting dentofacial deformities. For example, Norholt et al²⁸ included a portion of the zygoma in their "extended" LFI osteotomy. It is speculated that variations in design, such as zygomaticomaxillary osteotomies,²⁸ horseshoe osteotomies,³³ and midline osteotomies,²⁹ might sever vessels that are otherwise preserved in a conventional LFI osteotomy. This could account for greater variations in PBF and pulpal sensitivity noted after these procedures.

Moreover, the influence of segmentation of the maxilla and the level of the osteotomies on pulpal reactivity is speculated. Emshoff et al³⁴ reported that the odds of developing adverse outcomes were greater following segmented versus nonsegmented surgery. It has been shown that segmentation of the maxilla compromises pulpal sensitivities of teeth adjacent to the vertical osteotomy line.^{13,25,29,34} This compromised sensitivity could be the effect of placing the vertical osteotomy in a narrow interradicular space. Perhaps presurgical orthodontic separation of the roots by at least 2 mm at the cemento-enamel junction, and 4 mm at the apical third, could have avoided vascular compromise or damage to roots adjacent to the interdental osteotomies.⁴¹ It is likely that using the selective alveolar decortication technique in combination with LFI⁴² could have prevented devitalization of the pulp. Thus, it is conceivable that osteotomy-related factors such as damage to interdental bone, effects of heat generation, design of the osteotomy, compression of surrounding tissues, magnitude of mobilization, and orientation of the osteotomized segment may also affect pulp reactivity.

Two-thirds of the included studies^{9,23,27,31-33} reported that patients received orthodontic treatment in conjunction with LFI osteotomy. Information on the duration of the presurgical orthodontic treatment, or the extent of the postsurgical orthodontic maintenance might have clarified the influence of orthodontic treatment on pulp reactivity following LFI surgery. It is known that although orthodontic treatment itself may not jeopardize PBF, a history of dental trauma could be a risk for loss of pulp vitality during orthodontic treatment.⁴³ The maxillary teeth could be traumatized due to severing of the vessels during surgery. Application of



orthodontic forces in previously traumatized teeth could result in loss of pulp vitality.^{44,45} Therefore, combining orthodontic treatment with LFI surgery may negatively impact PBF and pulpal sensibility.

CONCLUSIONS

The results of this systematic review show that pulp vitality may be compromised in the immediate postoperative period (1 to 10 days). However, there might be an improvement in vascular and neural response, with time. Additionally, canine and premolars are most likely to have jeopardized vitality following LFI osteotomy. Clinically, it might be helpful to educate the patient regarding possible loss of vitality after LFI osteotomy, and the likelihood of its improvement with time. Additional evaluation of teeth for loss of vitality and subsequent development of periapical or periodontal pathology, especially if surgery is followed by a period of postoperative orthodontic therapy, may be meaningful. Perhaps clinical and radiographic signs such as tooth discoloration, obliteration of pulp chambers, and external resorption in patients treated with LFI osteotomy may indicate reduced chances of recovery of pulpal vitality. There may be a need for more vigilant oral prophylaxis to reduce the risk of infections to the healing osteotomy segments.

Further studies with standardized protocols are warranted to determine the influence of the LFI osteotomy on pulpal responsiveness in the long term.

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Appendix 1 Excluded studies

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